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ASSESSMENT OF SHIP DYNAMICS PROGRAMS FOR POSSIBLE INTEGRATION INTO THE INTEGRATED SHIP DESIGN SYSTEM

by

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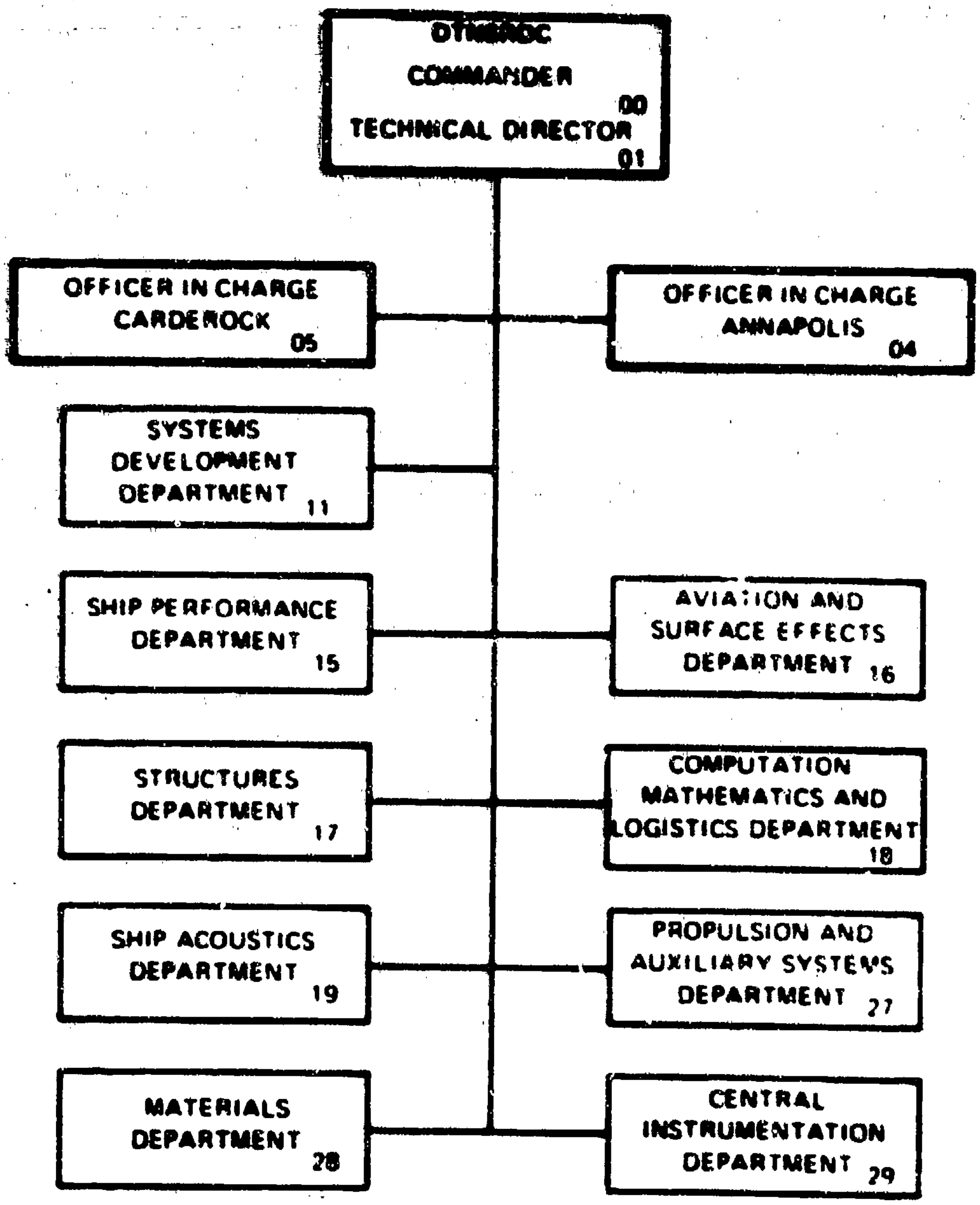

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The Integrated Ship Design System (ISDS), is in development to permit preliminary ship design to be accomplished using interactive computing. Currently ISDS does not address ship dynamics and this report explores programs in this discipline for inclusion in ISDS. A literature search was performed to identify, classify, and tabulate computer programs involving ship dynamics. The search included programs addressing motion

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prediction, added resistance in waves, slamming, deck wetness, and maneuvering for displacement hulls, hydrofoils, surface effect ships, air cushion vehicles, planing hulls, and catamarans. Candidate programs were analyzed with respect to their input data requirements and the relationship of these requirements to the flow of data among existing design programs of the Integrated Ship Design System (ISDS), and two dynamics programs for displacement hulls are recommended for integration into ISDS.

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ABSTRACT

The Integrated Ship Design System (ISDS), is in development to permit preliminary ship design to be accomplished using interactive computing. Currently ISDS does not address ship dynamics and this report explores programs in this discipline for inclusion in ISDS.

A literature search was performed to identify, classify, and tabulate computer programs involving ship dynamics. The search included programs addressing motion prediction, added resistance in waves, slamming, deck wetness, and maneuvering for displacement hulls, hydrofoils, surface effect ships, air cushion vehicles, planing hulls, and catamarans. Candidate programs were analyzed with respect to their input data requirements and the relationship of these requirements to the flow of data among existing design programs of the Integrated Ship Design System (ISDS), and two dynamics programs for displacement hulls are recommended for integration into ISDS.

I. INTRODUCTION

A. NEED FOR THE STUDY

The Navy's Computer Aided Ship Design and Construction (CASDAC) program addresses the task of employing computer programs to improve design, reduce design costs, and speed up the design process. CASDAC is generally concerned with the status of computer programs and with fostering the use of good programs in the ship design process.

A major component of CASDAC is the Integrated Ship Design System (ISDS), a collection of coordinated naval design programs which interface with a common data base to form a powerful design tool. The system reduces calendar time for the design process by facilitating programs' input and output and by use of interactive graphics and teletype modes of design program operation. There are currently no ISDS programs which address ship dynamics. There is increasing interest in the Navy to consider the manuvering and seakeeping characteristics of ships early enough in the design cycle that they may effectively impact the design. Inasmuch as ISDS does not presently address ship dynamics, it is proposed that compatible dynamics programs be obtained or developed for inclusion in ISDS.

B. OBJECTIVE

The objective of this task was to determine what ship dynamics programs are available and to identify any candidate programs suitable for inclusion in ISDS.

C. SUMMARY OF TASK

The task performed was to make a literature search for computer programs involving ship dynamics, tabulate the programs found from this literature search, and assess the potential usage of these programs in ISDS.

D. SCOPE OF STUDY

1. Ship Types - The literature search was directed toward finding computer programs involving the following vehicle types:

Naval and Commercial Displacement Ships
Hydrofoils
Surface Effects Ships (SES)
Air Cushion Vehicles (ACV)
Planing Hulls
Catamarans

2. Topics of Interest - The specific topics of interest in this literature search are the following:

Motions Predictions
Added Resistance in Waves
Slamming
Deck Wetness
Maneuvering

II. GENERAL APPROACH

A. LITERATURE SEARCH

The following literature searches were conducted to determine what programs are available:

A literature search of the DTNSRDC library

A Maritime Research Information Service (MRIS)

A Defense Documentation Center (DDC) literature search

A Ship Automatic Retrieval Project (SHARP) literature search

In order to assess the ship dynamics programs, information was tabulated on each program found in the above literature searches.

B. CONSULTATION WITH EXPERTS

Experts in the field of ship dynamics at DTNSRDC were consulted to determine if any significant ship dynamics programs were missed in the literature search, and their recommendations were obtained for programs to be integrated into ISDS. The experts consulted were:

	Code	
Dr. Michel Kazuo Ochi	1506	Specialist - Naval Architect
Daniel S. Cieslowski	1507	High Performance Vehicles Program Office
Dr. Manley St. Denis	1513	Specialist - Naval Architect
Dr. Wen Chin Lin	1524	Design Evaluation Branch
Dr. Nils Salvesen	1552	Hydrodynamics Branch
Geoffrey G. Cox	1568	Surface Ship Dynamics Branch
Nathan K. Bales	1568	Surface Ship Dynamics Branch
Dr. Choung Mook Lee	1572	High Performance Craft Dynamics Branch

III. FINDINGS

A. TABULAR FINDINGS OF LITERATURE SEARCH

The findings of the literature search are presented as two tables in Appendix B. Table I is a list of the ship dynamics computer programs and a brief summary of each. Programs listed in Table I are those for which the library search yielded documentation or detailed discussion; Table I does not list programs for which the search produced references but no further discussion. The entries in Table I are ordered according to ship type and topic of interest, with the newest programs in each grouping listed first.

Table II is a list of publications encountered in the literature search which reference computer programs in ship dynamics, including some of the programs listed in Table I. Table II is also ordered according to ship type and topic of interest.

B. DISCUSSION OF FINDINGS

1. Six Degree of Freedom Programs - For conventional naval and commercial displacement ships, there are three 6-degree of freedom (pitch, heave, roll, sway, yaw, surge) programs which address the topic of motion prediction:

- The DTNSRDC Ship Motion and Sea Load Computer Program[1]*
- Program SCORES - Ship Structural Response In Waves[2]
- The MIT 6-Degree of Freedom Program[3]

All of these programs are based upon the compromise theory.**

*Superscripts refer to references in Section VII.

**Appendix A provides a brief discussion of several accepted theories which form the basis for various dynamics programs.

All three 6-degree-of-freedom programs compute the amplitude and phase for the pitch, heave, roll, sway, yaw, and surge motions, the vertical and horizontal shear forces, and the bending and torsional moments. Various of these programs also include other design features such as computation of hydrodynamic pressure distributions, deck wetness, added resistance and slamming.

The 6-degree of freedom programs require as input a physical description of the ship including hull offsets, ship speed, ship heading relative to waves, mass of the ship, mass distribution, and a representation of the sea condition.

2. Pitch - Heave Programs - Ship motion programs for the prediction of pitch and heave are numerous*, however, most of these programs are based on one of two theories the compromise theory or the Korvin-Kroukovsky theory.[5]

The Frank Close-Fit Ship Motion Computer Program[6] computes pitch and heave motions for ships in regular and irregular head waves. The regular wave responses are computed according to the compromise theory. The irregular seaway is represented by the Pierson-Moskowitz Sea Spectrum and statistical response parameters are computed for pitch and heave as well as for absolute and relative vertical displacement velocity and acceleration at any point along the length of the ship.

In the Frank Close-Fit Ship Motion Program, there are two methods used for computing the two-dimensional added mass and damping coefficients, the Lewis-form method and the close fit method. The Lewis-form method is fast but it is only accurate for regular (no knuckles, bulbous bows, etc.) common ship forms, while the close-fit method is time consuming but accurate for any station shape. The user has the option of selecting the best method for each station.

*Francis Ogilvie and Robert Beck present a review of the theory for predicting ship motions[4]

Another example of the 2-degree-of-freedom program is "Computer Aided Prediction of Seakeeping Performance in Ship Design" by T. A. Loukakis. The theory used in this program is essentially the strip theory of Korvin-Kroukovsky and Jacobs,[8] with the changes presented by Gerritsma and Beukelman[9]. The program will calculate the response operators (the ratio of the ship response to the wave amplitide) of pitching and heaving motions in regular waves, it will calculate motions, velocities, acclerations, relative motions, relative velocities, bending moments and shearing forces for any position along the ship, and it will calculate the mean added resistance of the hull form. The regular wave results are used in conjunction with the superposition principle to predict seakeeping behavior in a seaway, i.e., in a confused pattern of waves of various sizes, shapes, and directions. The results of the ship behavior in a seaway are then used in conjunction with statistical theory to predict additional seakeeping characteristics of a ship such as probility of occurrence of deck wetness, propeller racing, and slamming. Finally, the program can calculate the calm water resistance and propulsive coefficient of a hull form on the basis of Series 60 or Taylor Series, and it can calculate the calm water shearing forces and bending moments. In general the prediction of the additional seakeeping characteristics--deck wetness, propeller racing, and slamming--are not consistance with experimental results. The discrepancies can be attributed to the following reasons:

a) the ship operates at a different dynamic draft under speed (squat), and

b) local conditions prevailing at the bow and the stern are not predicted by theory.

Another method for predicting pitch and heave is the "standard series" approach. The technique for a standard series approach is to generate a family of hull forms with a systematic variation of all geometric variables which are expected to strongly influence seakeeping. The performance of these hulls is established (by model tests, full scale measurement, etc.) and data are recorded to produce an extensive data base which may be subsequently interpolated to predict performance of later designs.

The Entry and Solution Program (ESP)[10] uses a standard series approach to calculate the heave, pitch, relative motion and absolute acceleration. As ship motions do not appear to be sensitive to local details of hull shape, it is possible to select a simplified family of mathematical forms. Each mathematical model represents all hull forms having the same waterplane, profile, and sectional area curve. The mathematical model is further simplified by adopting a simple systematic set of waterplanes - each has a parallel midship segment together with fourth degree polynomials which swing into the centerline at the fore and aft perpendiculars without a discontinuity in curvature. The profile is rectangular, so all sections have the same depth.

3. Roll Motion - The calculation of the force-motion coefficients relating to roll motion is primarily a nonlinear problem.

Few programs exist expressly for the calculation of roll motion. The 6 degree of freedom programs include roll motions predictions and the portion of the program calculating the roll motions could be extracted from them. The 6 degree of freedom program by Salvesen et al. uses an inviscid strip theory to compute the linear components of wave damping. A quasi linear correction term was then added to account for the nonlinear viscous damping. The correction term depends on frequency, hull geometry, bilgekeel dimensions and viscosity. A trial and error procedure is used to solve the equations.

There is also in use at DTNSRDC the Conally Roll Program,[11] an unpublished roll program, in which linear theory is used to represent rolling motion. This program gives the rolling motion and moment of the ship in regular waves of any selected length and height, and this may be combined with any energy spectrum of wave slope to give a spectrum of motion in irregular waves. In irregular waves the response amplitude operators are calculated, and the RMS roll and moment are given.

4. Added Resistance - A number of programs exist for the prediction of added resistance in waves; Appendix A describes the theories upon which four of these programs are founded. Since added resistance programs require input data describing the motion of the ship, the programs are often setup to run in tandem with a ship motion program.

The added resistance programs calculate the added resistance in regular head seas for a number of wave encounter frequencies. Average added resistance of the ship proceeding at a certain speed in irregular head seas can then be predicted by superimposing the programs' added resistance in regular seas with the energy spectrum of the irregular sea.

5. Slamming and Deck Wetness - M.K. Ochi and L.E. Matter[12] present a method for prediction of slamming characteristics and hull responses of a ship at an early design stage, given input data describing the motion of the ship and certain hull form coefficients which are significant in slam prediction. The predictions include:

- frequency of occurrence of slam impacts,
- elapsed time before the next severe impact will occur,
- magnitude of impact pressure,
- the largest (extreme value) impact pressure most likely to occur,
- the extreme pressure for design consideration,
- ship speed at which bottom plate damage is most likely to occur,

- ship speed free from slam damage,
- limiting speed for which slam impact is tolerable for the crew,
- spatial distribution of impact pressure and resulting force,
- main hull girder responses such as whipping stress and acceleration to slam impact.

This method has not been completely programmed, however, portions of the method dealing with frequency of slam impact have been integrated into ship motion programs as design features.

The prediction of deck wetness has also been integrated into ship motion programs as a design feature. The relative motion between the ship and the water surface is obtained from the ship motion program. Standard correction factors are applied to adjust for flare and the effect of the ship's standing wave pattern.

6. Maneuvering - For conventional displacement ships there are maneuvering programs such as "A Digital Computer Technique Prediction of Standard Maneuvers of Surface Ships" by J. Strom-Tejsen[13] and "Directional Stability and Control of ships in Restricted Channels" by Haruzo Eda[14]. These programs require as input hydrodynamic force and moment derivatives which must be obtained from expensive captive model testing techniques. Captive model tests are performed by means of test facilities such as the rotating arm, oscillators, and the planar motion mechansim. The hydrodynamic derivatives depend largely upon the ship geometry and design and the derivatives differ significantly from one hull form to another. The hydrodynamic derivatives are by definition partial derivatives of a force or moment with respect to one or more of the motion variable. To obtain these derivatives it is necessary to force the model to execute various prescribed motions and to measure the forces and moments as functions of the different motion parameters.

There are special purpose programs for various classes of ships which do not require the hydrodynamic derivatives, but which are limited in application. These programs predict maneuvering as a function of various parameters, which define ship and rudder geometry, and which define operating variables.

The relationships used in these programs were derived by use of regression analysis techniques and the results of the programs are only applicable to ships similar to those in the data base.

7. Hydrofoil, SES, ACV, Planing Hulls - Programs for the prediction of ship dynamics of hydrofoils, surface effects ships, air cushion vehicles, and planing hulls are time domain programs. Time domain programs use simulation techniques to compute the dynamics of the vehicle during a succession of incremental time slices, thus giving a time history of the dynamics. The simulation of the dynamics is usually carried out by an analog program. It is usually not possible to write such programs that run in real time. The ratio of simulation time to real time sometime becomes as large as 100 to 1. An important factor in the motions of these ships is the auto pilot, the ship's real time control mechanism which interprets inputs from motion sensors and generates directives to the ship's active control devices. The auto pilot must, of course, be considered in the program for simulation of the ship dynamics. There is no general analog program for ship dynamics; one or more new programs

must be written for each ship. Most of these existing programs are not documented. Some of the specific programs which are documented are listed in Table I of Appendix B.

8. Catamarans - For the prediction of ship motion and loads of catamarans there are programs such as MIT's "CAT-5"[15]. This program is capable of predicting motions, velocities, and accelerations of catamarans moving in waves at any heading angle. The wave induced forces and moments on the catamaran cross-structure are also computed. These responses can be obtained in regular waves as well as long-crested or short-crested random waves. For the latter cases, the one-parameter Pierson-Moskowitz Wave Spectrum and the two-parameter Bretschneider spectrum are used. These spectra are defined in Section 1.d. of Appendix A.

The basic input to the program includes the overall dimensions of the catamaran, the form and spacing of the demi-hulls, the longitudinal and transverse weight distributions, the general heading angle and the description of the sea condition by wave spectra. The output of "CAT-5" consists of the five degrees of motion (surge neglected) and the wave induced forces and moments on the cross-structure.

There is also a ship motions program for catamarans being developed at DTNSRDC which is based on "Motion and Resistance of a Low Waterplane Area Catamaran" by P. C. Pien and C. M. Lee.[16] This method predicts characteristics of motion and hydrodynamic loads of either conventional catamarans, or small Waterplane Area Twin Hull Ships (SWATH). The equations of motion for catamarans are derived in the frequency domain under an assumption of a linear excitation-response relationship. The hydrodynamic coefficients involved

in the equations of motions are determined from strip theory, assuming slender geometry of each hull of the catamaran. The effect of forward speed on the hydrodynamics coefficient is treated as if there were no perturbation on the fluid due to the forward movement of the ship. An apparent underestimation of damping results in an unrealistically large motion amplitude at the resonant frequency. The introduction of supplemental damping into the equation of motion is needed to achieve a reasonable prediction of catamaran motions. The Supplemental damping is introduced into the equations of motion so as to be linearly proportional to the oscillation velocity. Prediction of statistical averages of motion amplitude for the catamaran in irregular seas is made by using the frequency response amplitude operator in conjunction with the Pierson-Moskowitz sea spectrum.

The probable frequency of a water contact with the cross-deck structure is computed for given conditions such as significant wave height, forward speed, and height of the cross-deck structure above the waterline. The formula used is based on a truncated Rayleigh's probability distribution for slamming and is similar to the formula developed by Ochi (1964) for bow slamming of monohull ships.

Respecting added resistance for catamarans, it has been shown that by using the concept of an "effective hull form" the added resistance for catamarans can be predicted with the same methods used for conventional monohulls.

IV. RECOMMENDATIONS FOR DYNAMICS PROGRAMS IN ISDS

A. RECOMMENDATION FROM THE DTNSRDC SHIP PERFORMANCE DEPARTMENT

The Ship Performance Department made the following recommendations concerning programs for integration into ISDS:

- Candidate programs should address pitch, heave and loads in head seas and roll in beam seas, because these conditions represent the worst motions and loads.

- A pair of programs - one for pitch-heave-loads in head seas and one for roll in beam seas - are recommended for use early in the ISDS design process, and another similar pair for more exact analysis later in the process. These four programs are:

  <u>For early use</u>:

  - For pitch and heave, the Entry and Solution Program which uses a standard series approach.

  - For roll, the Conolly Roll Program.

  <u>For later, more exact analysis</u>:

  - For pitch-heave-loads, the Frank Close Fit Ship-Motion Computer Program.

  - For roll, the DTNSRDC Ship-Motion and Sea-Load Computer Program.

These recommended programs are described in Appendix C.

B. ISDS DESIGN PROCESS CONSIDERATIONS

The four programs recommended by the Ship Performance Department were scrutinzed by DTNSRDC Code 1853 with respect to the input data required by each. The sequence of ISDS programs (See Figure 1) was examined to identify the earliest point in the ISDS process at which data is available to allow execution of the four recommended dynamics programs.

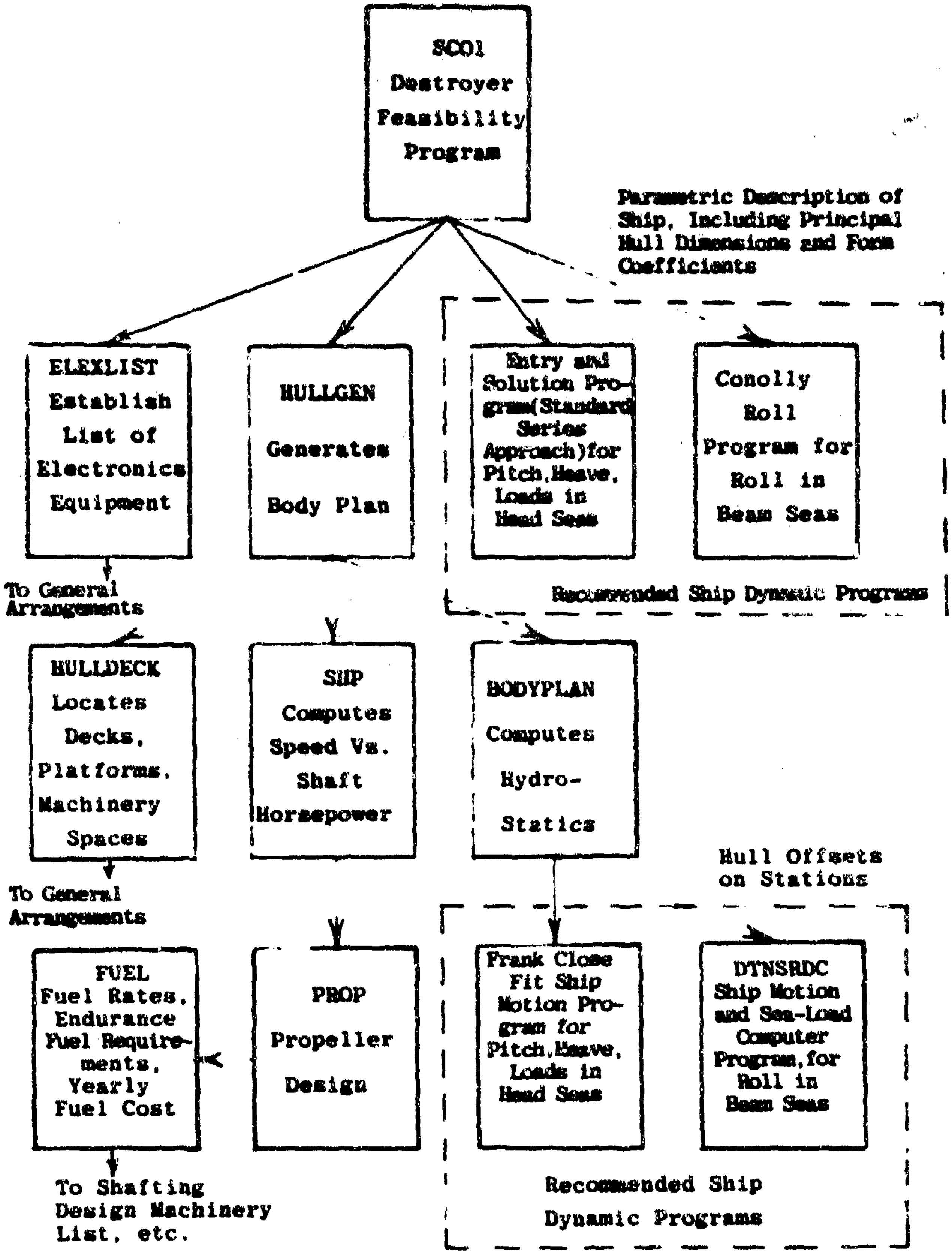

Figure 1 - Portion of ISDS Design Process

The findings of this examination are as follows:

- The principal significant difference among the four programs respecting input requirements is that the hull form is described to the pair of early programs merely in terms of basic hull dimensions and form coefficients, whereas the two more exact programs require a table of offsets on hull stations.
- The two more exact programs also require input respecting the dynamic properties of the ship (center of gravity, radii of gyration, etc.), roll damping and bilge keel description. Data for the dynamic properties and roll damping can be satisfactorily estimated from known properties of similar ship types. Feasible bilge keel configurations can be assumed and verified. All these data can be compiled by the engineer subsequent to the operation of SCO1.
- Hull offsets are produced by the second ISDS design procedure, HULLGEN/BODYPLAN. These offsets are not faired, but they are considered to be acceptable for use in the two more exact dynamics programs.

Given that the two more exact programs can be exercised so early in the ISDS design process, it would be difficult to justify the effort of integrating into ISDS all four dynamics programs. However, three alternative rationales which use all four programs have been identified and briefly examined; none of these rationales are considered to merit further development:

(1) Rationale: The two early programs could be executed after SCO1 and in parallel with or prior to HULLGEN/BODYPLAN, thus verifying the seakeeping characteristics earlier in the design process.

Retort: HULLGEN/BODYPLAN can be executed in 1 - 3 days and this small difference does not justify the extra implementation cost.

(2) Rationale: The two early programs could be incorporated within SCO1 itself, and seakeeping considerations would be available early enough to influence the selection of hull dimensions and form coefficients.

Retort: The two early programs, as they presently operate, are major programs in their own right, and require modest CPU time to execute. Operation of these programs within SC01 to examine each of a large matrix of possible designs would absorb very much computer time, increasing markedly the operation cost of SC01. Furthermore, a major coding effort would be required to join the programs. If indeed a measure of seakeeping is needed in this formative design step, it would seem that a faster, less precise routine should be developed to better meet the need.

(3) Rationale: At the stage of design represented by HULLGEN/BODYPLAN the design is still fluid, and the dynamics programs may have to be executed many times; programs which are cheap to operate are desirable for the early iterations.

Retort: The more exact roll program runs in less than one minute of CPU time, so there is not much to be saved by avoiding its use. The Frank Close-Fit Ship Motion Computer Program may be operated in a "quick-and-dirty" mode utilizing a built-in Lewis form to represent the hull form. Execution time would presumably be reduced, as would the precision of the results, but the user would enjoy the option to run in either mode.

C. RECOMMENDATION FOR INTEGRATED SHIP DESIGN SYSTEM

The Frank Close-Fit Ship-Motion Computer Program should be used to investigate pitch, heave and loads in head seas, and the NSRDC Ship-Motion and Sea-Load Computer Program should be used to investigate roll in beam seas. Both programs should be integrated into ISDS such that they could be executed at any time after the ISDS design procedure HULLGEN/BODYPLAN has been run (Figure 2).

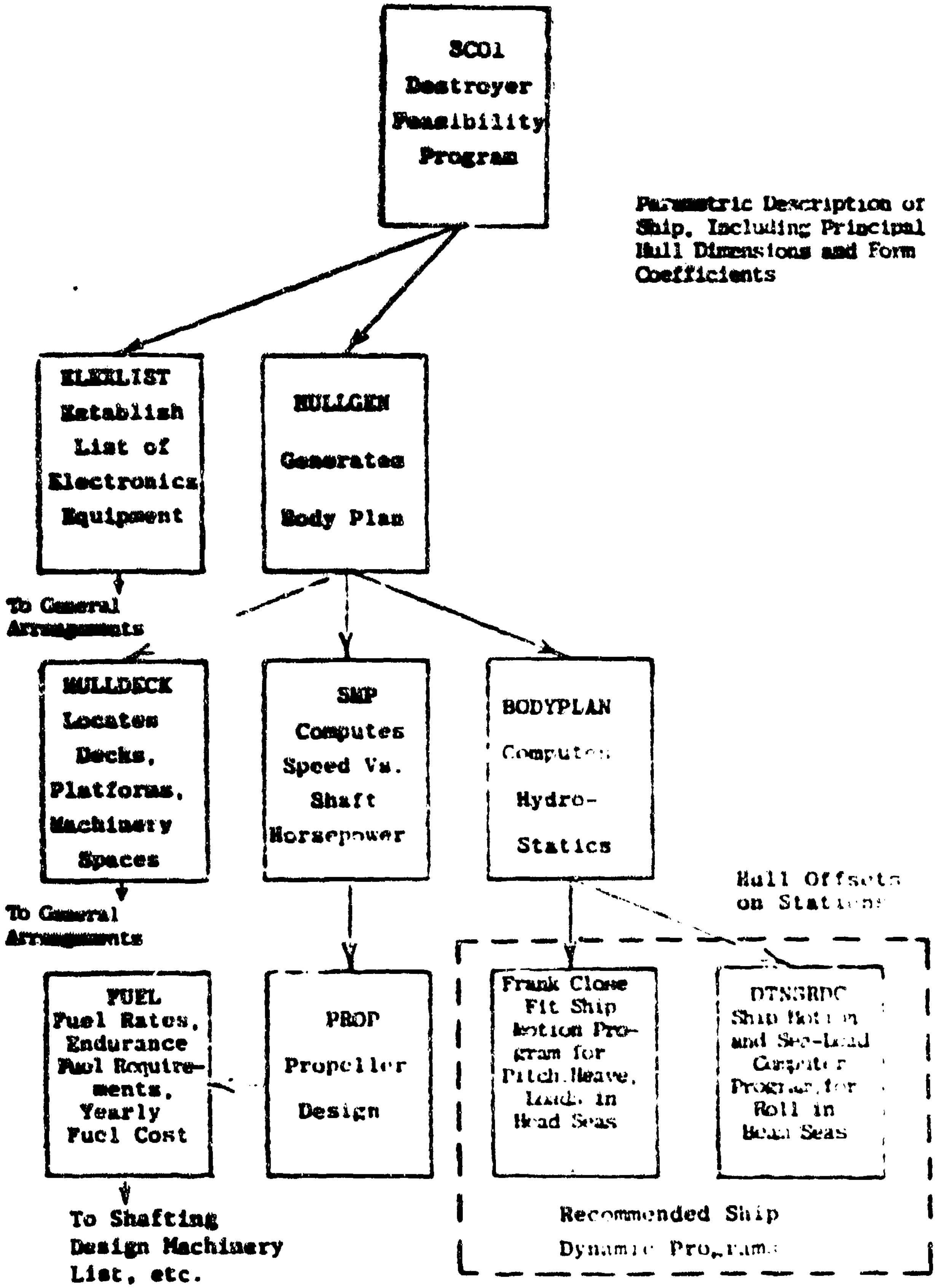

Figure 2 - Portion of ISDS Design Process, Illustrating Recommended Integration of Ship Dynamics Programs

V. SUMMARY AND CONCLUSION

A literature search for computer programs involving ship dynamics was performed. The programs found in this literature search are listed with a brief description of each in Appendix B.

The programs recommended for integration into ISDS are as follows:

- The Frank Close-Fit Ship Motion Computer Program should be used to investigate pitch, heave and loads in head seas.
- The NSRDC Ship-Motion and Sea-Load Computer Program should be used to investigate roll in beam seas.

Both programs may be executed very early in the ISDS design sequence.

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APPENDIX A

THEORIES USED IN SHIP DYNAMIC COMPUTER PROGRAMS

APPENDIX A

THEORIES USED IN SHIP DYNAMIC COMPUTER PROGRAMS

Presented in this appendix is a brief description of some widely used theories which have been programmed to predict ship dynamics.

1. SHIP MOTIONS

a. Strip Theory

In strip theory the ship is assumed to be a slender body, i.e., the beam and draft are small compared with the length. Because of the slenderness of the body, it is assumed that the major fluid motion around the body is in the transverse directions; there is not enough frontal area to cause important longitudinal fluid motion. In this case, the flow in a transverse cross-section can be described by the laws of fluid motion in two dimensions.

The theories which are presently used in the computer prediction of ship motion are the Compromise Theory and the Korvin-Kroukovsky Strip Theory. Both of these are strip theories in which it is assumed that the fluid is inviscid. The viscous effects (damping) are small and can be disregarded except in the case of roll motion.

b. Compromise Theory

The compromise theory, as described by Salvesen, Tuck and Faltinsen[17] rests upon three principal assumptions:

- The hull form is assumed to be a slender body, i.e., the beam and draft are small compared with the length. More precisely, any planes tangent to the hull should be nearly paralled to the longitudinal axis.
- It is assumed that there are no significant interactions between the unsteady flow and the steady disturbance caused by the forward motion of the ship.
- It is assumed that the velocity potential function in the final equation for the ship motion transfer functions can be evaluated stripwise.

The compromise theory can predict the heave, pitch, surge, sway, roll, and yaw motions as well as the wave-induced vertical and horizontal shear forces, bending moments, and torsional moments for a ship advancing at constant speed in regular waves.

Under the assumptions that the responses are linear and harmonic the six linear coupled differential equations of motion can be written in the following form:

$$\sum_{K=1}^{6}\Big[\underbrace{(M_{jk}+A_{jk})\ddot{n}_k}_{\text{inertia forces}}+\underbrace{B_{jk}\dot{n}_k}_{\text{damping force}}+\underbrace{C_{jk}n_k}_{\text{hydrostatic force}}\Big]=F_j e^{i\omega t}\,,\quad j=1\cdots 6$$

where:

M_jk are the components of the generalized mass matrix for the ship

A_{jk} are the added mass coefficients

B_{jk} are the damping coefficients

C_{jk} are the hydrostatic restoring coefficients

n_k are the translatory and angular displacements

$\dot{n}_k$ are translating and angular velocities

$\ddot{n}_k$ are translating and angular accelerations

F_j are the complex amplitudes of exciting force and moment

ω is the frequency of encounter

i = $\sqrt{-1}$

e = exponential constant

The six coupled equations of motion reduce to two independent as sets of coupled linear differential equations with frequency and speed dependent coefficients. This reduction is made possible by recognizing the lateral symmetry of a ship. One set of three coupled equations are expressions for surge, heave, and pitch and another set of three coupled equations for sway, roll, and yaw. Thus for a ship with lateral symmetry, surge, heave, and pitch are not coupled with sway, roll, and yaw. The equations for the wave induced loads are expressed in terms of the resulting motions and the derived hydrodynamic coefficients.

The agreement between the compromise theory and experiment is very satisfactory for the heave and pitch motions and for the vertical loads, in oblique and following waves as well as in head waves. Good agreement is also obtained for the coupled sway and roll motions in beam waves. Due to lack of experimental data, it has not been possible to confirm by experiment the theroretical motions for sway, yaw, and roll in oblique waves. Nevertheless, the good agreement shown for the horizontal shear forces, bending moments and torsional moments in oblique waves suggests that the theory may also predict the horizontal motions quite well.

c. Korvin-Kroukovsky Theory

While the compromise theory is an analytical approach, the Korvin-Kroukovsky theory[8] is based on ingenious and careful physical arguments. Because the Korvin-Kroukovsky theory is a strip theory, the flow around the ship is a 2-dimensional problem. From the solution of the 2-dimensional boundary value

problems of the flow, one can compute the hydrodynamic pressure distribution on the ship caused by its own motion; thus one can also compute added mass and damping forces.

It is not easy to compute the exciting forces due to waves, but Korvin-Kroukovsky made a simple assumption: In the added-mass and damping problem, he replaces the velocity and acceleration of the ship cross-section by an effective relative velocity and acceleration of that section with respect to the instantaneous water surface.

Finally it was necessary to introduce some correction for the effects of forward speed. One effect is the Doppler shift in the frequency of encounter of the ship with the waves. The second effect is that the forward motion of the ship causes an apparent cross-flow in a transverse cross section if the ship happens at some instant to have a non-zero pitch angle.

Reasonably accurate prodictions are obtained from the Korvin-Kroukovsky theory. . The theory accurately predicts the heave and pitch motions as well as the vertical shear forces and bending moments for regular cruiser stern ships. Predictions are less accurate for ships with bulbous bows, knuckles, transom sterns, and other irregular features.

d. Motions in Irregular Seas

A very good description of irregular sea computations is contained in the Frank Close-Fit Ship-Motion Computer Program by W. Frank and N. Salvesen[6] and is quoted as follows:

"The motions of the ship in irregular seas are analysed in a statistical manner following the procedure of St. Denis and Pierson.[18] The statistical approach does not give the actual time history of the motions but rather a statistical description of the response.

"The procedure can be outlined in short as follows: It is assumed that both the excitation (the irregular sea) and the responses (the ship motions) are random processes which can be assumed to be stationary Gaussian. Under this assumption an adequate statistical knowledge of the sea elevation and the ship responses are determined completely by their respective energy spectra. The energy spectrum is a function which specifies the fraction of the total energy which is associated with any given frequency band. The sea energy spectra are known functions furnished by the oceanographer, while the response spectra must be computed.

"The second fundamental assumption is that the linear superposition principle is applicable to this problem. This assumption leads to a simple relationship between the sea spectra and the ship response spectrum. More specifically, St. Denis and Pierson[19] stated that 'it is assumed that the sum of the responses of a ship to a number of simple sine waves is equal to the response of the ship to the sum of the waves.' Under this assumption the ship response energy spectrum is

$$S_R(\omega) = [R(\omega)]^2 \cdot S_S(\omega)$$

where $R(\omega)$ is the amplitude of the response to a sinusoidal wave of unit amplitude, $S_S(\omega)$ is the sea energy spectrum and ω is the wave frequency. Hence, the ship response spectrum $S_R(\omega)$ which completely describes statistically the ship motions in the irreqular sea is given in terms of the response amplitudes which are obtained by the strip theory ... and the sea spectrum which is a known function."

The following three sea spectra are often used in irregular sea calculations:

The Neumann Sea Spectrum

The Bretschneider Sea Spectrum

The Pierson-Moskowitz Sea Spectrum

The Neumann Sea Spectrum is a single parameter spectrum which describes fully developed seas as a function of wind speed:

$$S_s(\omega) = \frac{2g^2\pi^3}{\omega^6} C e^{-\frac{2g^2}{w^2\omega^2}}$$

$S_s(\omega)$ = sea energy spectrum

where g = acceleration of gravity

C = a constant (8.27 X10^{-4})

w = wind speed

e = expotential constant

ω = frequency of wave pattern

The Bretschneider is a two parameter (significant wave height and mean period of waves) sea spectrum for describing developing and decaying seas

$$S_s(\omega) = A\omega^{-5}e^{-Bw^4}$$

where $S_s(\omega)$ = sea energy spectrum

A = $4\pi^3 h_{\frac{1}{3}}^2/Tm^4$

B = $16\pi^3/Tm^4$

$h_{\frac{1}{3}}$ = significant wave height

Tm = mean period of waves

ω = frequency of wave pattern

w = wind speed

The Pierson-Moskowitz Sea Spectrum is a single parameter (significant wave height) sea spectrum for describing fully developed seas:

where: $S_s(\omega) = A\omega^{-5} e^{B\omega^{4}}$

$A = .0081g^2$

$B = 33.56/h_{\frac{1}{3}}^2$

e. Roll Motion

The linear methods used in computer programs for the compromise and Korvin-Kroukovsky theories do not acceptably predict roll motion due to its characteristic non-linear nature.

Although much work has been done in other fields to develop methods for the efficient solution of nonlinear problems, little use has been made of these methods in the field of ship hydrodynamics.

In pure roll motion there are two principle sources of nonlinearity. The first is the nonlinear restoring force. At large roll angles the righting moment curve may not remain linear with heel angle. The degree of the nonlinearity depends on the ship form. The other source of nonlinearity in roll motion is the damping force. Roll damping comes from three sources: frictional damping, energy lost in eddy making, and the damping due to wave making. Frictional and eddy making damping are both due to viscous effects and are essentially nonlinear with respect to roll velocity. Wave damping is associated with the energy carried away from the rolling ship by the generated waves and can be predicted fairly well using linear theory.

In the technique for prediction of roll used in the Compromise Theory as described by Salveson, Tuck and Faltinsen, the viscous roll-damping effects are introduced into the equation of motion as a quasilinear term. This term is the product between the maximum roll velocity and a constant which depends

on the frequency, the viscosity, the bilge-keel dimensions, and the hull geometry. The maximum roll velocity is estimated before the motions are computed. If the difference between the estimated and the computed maximum roll velocity is too large, a new value for the maximum roll velocity must be estimated and the motion then recomputed until the two converge.

A linear theory for the prediction of roll is presented by J. E. Conolly[11](1969). In this theory it is assumed:

- the ship is wall-sided at the waterline
- the buoyancy forces are distributed along the length, their magnitude depending upon the local sectional area of the ship
- the local force is assumed to act normal to the local wave surface

Integrating over the length of the ship leads to an effective wave which is less steep than the true wave, and which has a frequency equal to that with which the true wave is encountered.

In view of the above simplifying assumptions, it is considered justified for ease of solution to replace the ship by a simple "equivalent" hull having rectangular sections and a constant draft. For fine warship forms the design waterline can be reasonably represented by a parabola having maximum width at amidship and zero half-breadths at the ends. Elliptical and rectangular waterplanes forms are also available. The vertical center of gravity of the equivalent hull is placed between the center of buoyancy and the metacenter in the same relative position as that of the real ship (i.e., $\overline{BM}/\overline{GM}$ is the same for both).

The "response amplitude operator" relates the roll responses of the ship to various regular waves, and is defined as the maximum roll angle divided by wave slope. Wave slope is represented as a function of frequency of wave pattern, wave direction relative to the ship, and ship speed. The following information is required to compute the roll response amplitude operator for a particular ship in a particular wave pattern:

- The natural period of roll in still water
- The ratio of added hydrodynamic inertia to the ships mass
- The distances between vertical center of buoyancy vertical center of gravity and metacenter
- The damping moment per unit roll velocity as a function of ship speed. This moment can be expressed non-dimensionally in terms of a coefficient of roll decay which defines the manner in which rolling oscillation would decay after removal of the rolling moment.

2. ADDED RESISTANCE

Respecting the topic of added resistance in waves for conventional ships, there are four distinct theories:

Potential flow solution, by Maruo
Drift force approach, by Joosen
Pressure distributions, by Boese
Radiated energy approach, by Gerritsma & Beukelman

These theories are presented and compared by Jorgen Strom-Tejsen, et. al.[20]

The theory developed by Maruo is a potential flow solution to the problem, in which the velocity potential is divided into three components which are considered separately. A singularity distribution is used to represent the hull form, and the wave field potential consists of the potential associated with the regular wave field and velocity potential of the waves produced by the singularities. Maruo has shown that the pitching and heaving motion of the ship dominates the effects of surge, and he was therefore able to neglect the effects of speed variation.

In application of the theory, Maruo has further approximated the ship hull by a line distribution of sources, thereby allowing the evaluation of the added resistance in terms of the geometric characteristics of the ship (described at each section) and the measured or computed ship motion.

The added resistance theory formulated by Joosen is based on the extension of a drifting-force-in-waves theory to the case of a ship under way. The drifting force problem was completely analyzed by Maruo and extended by Newman. Maruo determined the drifting force as a function of the motion of the ship and the wave reflection from the ship hull. Newman's contribution was an extension of the theory to include the

determination of vertical moment and the derivation of approximate expressions for slender ship in long waves.

Joosen has expanded Maruo's drift force expression in an asymptotic series of powers of a slenderness parameter and has truncated the series after the first order terms. The resultant slender body approximation for the drift forces is valid for short waves. The theory is extended to account for the added resistance in waves at ahead speed by the substitution of a wave encounter frequency which is a function of velocity for the wave frequency appearing in the analysis.

Joosen has shown that the drift force in the longitudinal direction in head waves is dependent only upon the potential of the radiated waves. He has concluded that if the ship motion amplitude is of a similar order of magnitude over the entire range of encounter frequencies, the wave diffraction effect may be neglected everywhere except for very small waves where it becomes dominant.

Joosen's final expressions are equivalent to those derived by Havelock except for the inclusion of a wave-motion coupling term. The added resistance is determined through a knowledge of the ship's frequency dependent damping coefficients as well as information on the heaving and pitching motion and phase relationships.

Boese has recently studied the added resistance problems using an approach similar to the original work performed by Havelock, but considering a more sophisticated approach to the initial motion data. Boese states that since the three-dimensional pressure distribution on a ship in waves cannot presently be determined, it is necessary to employ linear strip theory for computing the ship motions, and hence also for the pressure distribution.

The pressure forces acting on a ship are divided by Boese into two segments:

- The fluctuating force caused by the wave field and the heaving and pitching motion over a fixed surface, i.e., the hull below the static waterline.

- A correction to the fixed surface force to account for forces over regions of the hull which are not continuously immersed. For this correction, dynamic forces are neglected and a linear pressure distribution is assumed to be effective.

Computing the time average contribution to the longitudinal force completes the calculation of added drag.

Boese justifies his method on the ground that first order effects dominate in motion responses.

The method used by Gerritsma and Beukelman to calculate added resistance is to compute the energy flux radiated from the hull. The energy is found in terms of the sectional damping coefficient and the vertical relative water velocity between the ship and the wave. The radiated energy is then equated to the work being done by the ship. Gerritsma theory has the advantage that the added resistance is easy to compute if one is already computing the motions from strip theory. Also the radiated energy approach gives perhaps the easiest description of resistance in quartering and beam seas. The added resistance in oblique seas is found by considering the energy radiated from each side of the ship separately.

3. SLAMMING

Michel K. Ochi and Lewis E. Motter present a method to predict the slamming characteristics and hull responses of a ship at an early design stage. A statistical approach to the development of a prediction method is taken.

The following is a brief outline of the overall prediction method. Two prerequisites have to be prepared in advance. One is the description of ship motions and the other is the evaluation of coefficient associated with slam impacts. A computer program to evaluate the coefficient for a given section shape is available in refcrence 20.

With these two prerequisites in hand, the following predictions can be made:

a. Frequency of Occurrence of Slam Impact. This can be easily obtained from the information on ship motion and velocity relative to waves.

b. Limiting Speed for Which Slamming Impact is Tolerable. From results obtained in Item a as a function of ship speed, the limiting speed for which slam impact is tolerable - hereafter referred to as tolerable speed for slam impact - is estimated as the speed for which either the probability of slam impact at Station 3 reaches a level of 0.03 or the significant amplitude of the vertical bow acceleration reaches a level of 0.4 g. This subject is discussed later in the section on ship speed and slamming damage.

c. Time Interval Between Successive Impacts. From results obtained in Item a the time interval between successive impacts can be estimated.

d. Slamming Pressure. The probability function necessary for predicting impact pressure is established from the ship motions and coefficient associated with slam impacts thus the average and significant values of impact pressure can be predicted.

e. Elapsed Time Before the Next Severe Impact. The time between one severe impact and the next at a specific location along the ship length can be estimated from the results obtained in Items a and d.

f. Most Probable Extreme Pressure. By applying order statistics, the magnitude of the largest impact pressure most likely to occur in a specified ship operation time in a given sea can be predicted at any location along the ship length from the results obtained in Item d.

g. Ship Speed at Which Bottom Plate Damage is Most Likely to Occur. By equating the pressure magnitude obtained in Item f to that which will cause permanent set of a rectangular plate, the speed is estimated at which bottom plate damage is most likely to occur.

h. Extreme Pressure for Design Consideration. The magnitude of extreme pressure for design consideration can be estimated by applying order statistics to the probability function obtained in Item d. The extreme value is controlled by a preassigned small probability of being exceeded, which the designer specifies.

i. Ship Speed Free From Slam Damage. By equating the pressure magnitude obtained in Item h to that which will cause permanent set of a rectangular plate, the attainable (maximum) speed below which no plate damage would occur is estimated. The probability of occurrence of damage is the small number assigned in item h.

j. Slam Impact Force. The magnitude of impact force can be estimated from Items f or h, taking spatial distribution and traveling time of the pressure into consideration. The force evaluated using the extreme pressure in Item h is used for design consideration.

k. Main Hull Girder Response to Impact. Using the information obtained in Item J as an input, the main hull girder responses such as whipping stress and deceleration due to impact are estimated by solving a mathematical model representing the hull structural characteristics. Available computer programs for dynamic response of the hull may be used with necessary alterations.

According to M. K. Ochi and L. E. Motter (1973), a complete method to estimate in the design stage the slamming characteristics and hull responses of a ship, including the estimation of ship speed for which damage on bottom plating could possibly occur, is not available at present. There are, however, numerous papers on methods to obtain limited information on slamming including both theoretical and experimental approaches.

4. MANEUVERING

In order to calculate the path of a ship the hydrodynamic force and moment derivatives, which are by definition partial derivatives of a force or moment with respect to one or more of the motion parameters, must be known. The only way to obtain these derivatives is from captive model tests. Captive model tests are performed by means of test facilities such as the rotating arm, oscillators, and the planar motion mechanism.

The hydrodynamic derivatives depend largely upon the ship geometry and design and in general they differ significantly from one hull form to another. To obtain the hydrodynamic derivatives it is necessary to force the model to execute various prescribed motions and to measure the forces and moments as functions of the different motion parameters.

The hydrodynamic force and moment derivatives are used in combination with the equations of motion to calculate the path of a ship.

APPENDIX B

TABULAR FINDINGS OF LITERATURE SEARCH

Appendix B is presented as two tables. Table I is a list of the computer programs dealing with ship dynamics found in the literature search and includes a brief summary of each program. Table II is a list of publications encountered in the literature search which reference computer programs in ship dynamics.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Meyers, W.G., and Bales, S.L., "Manual NSRDC Irregular Sea Response Prediction Computer Program," to be published, NSRDC Report No. 4022	Displacement	Motions Prediction	The ship responses to long-crested, irregular waves are found by summing the ship responses to regular waves for all frequencies.
Sheridan, D.J., Meyers, W.G., Salvesen, N., "Manual O NSRDC Ship-Motion and Sea-Load Computer Program," NSRDC Report No. 3376, February 1975.	Displacement	Motions Prediction	A description of the "NSRDC Ship-Motion and Sea-Load Computer Program" is presented. This program computes the six-degree-of-freedom ship motions, wave-induced loads, and pressure distribution for a ship advancing at constant speed with arbitrary heading in regular waves.
Rubis, C.J., Harper, T.R., "Governing Marine Propulsion Gas Turbines in Regular Waves, NSRDC Report No. 4295, June 1974.	Displacement	Propulsion Motions Prediction	In this study, a digital computer simulation of a single-screw destroyer escort study ship driven by the General Electric LM 2500 gas turbine engines operating in a regular seaway was completed. Both gas-generator and shaft-speed governed systems with various design options were evaluated under different conditions of wavelength, ship speed, and pitch-heaving ship motions. In addition, a separate simulation using a computerized version of Maruo's theory was completed to predict pitch, heave, and mean added resistance for the study ship in head waves.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Bovet, D.M., "Development of a Time Domain Simulation for Capsizing in Following Waves," U.S. Coast Guard, Report No. USCG-D-28-74, October 1973.	Displacement	Motions Prediction	The report describes the development of a time domain computer simulation for ship capsizing in following waves. A survey of the recent literature in this field is presented. The formulation of the present approach is discussed, along with computer program limitations and assumptions. The program developed is used to study the phenomenon of low cycle roll resonance as demonstrated by a two-dimensional section in forced heave motion and by a fast cargo liner in following waves, both regular and irregular.
Beukelman, W., Bijlsma, Mrs. E.F., "Description of a Program to Calculate the Behavior of a of a Ship in a Seaway (Named: TRIAL)," Laboratorium Voor Scheepsbouwkunde, Technische Hogeschool Delft, Report No. 383, August 1973.	Displacement	Motions Prediction	In this report a description is given of a computer program to calculate vertical ship motions, shearing forces, bending moments, relative motions, vertical accelerations, slamming, shipping and increased resistance in regular and irregular waves with the well-known strip theory. For an arbitrary direction of wave travel irregular seas are supposed to be composed of uni-directional waves. The influence of the horizontal motions has been neglected and for this reason the direction of wave travel is practically restricted. The Lewis-form method is used for computing the two dimensional added mass and damping coefficients for all sections, even bulbous ones.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Ratanaruang, A., "Digital Computer Simulation for Surface Ship Control," Naval Postgraduate School, June 1973.	Displacement	Motions Prediction	Digital simitations of the dynamics of the surface ship in three degrees of freedom are done.
Daffer, G., Rogers, D., "Simulation of the Compatibility of an Air Capable Ship and a VTOL Aircraft," CADCOM, Inc., Report No. CADCOM-73-6, March 1973.	Displacement	Motions Prediction	An interactive computer simulation, LARC-I, has been designed to solve the nonlinear equations of motion of a generalized VTOL aircraft taking off from or landing on the deck of a ship moving in an irregular or random seaway. This version of LARC-I is limited to longitudinal motions, but is designed for eventual expansion to all degrees of freedom. The LARC-I programs makes use of ship motion amplitudes and frequencies derived separately in a ship motions program, wherein the forcing functions of the seaway are based on a stochastic representation of the waves for any given sea state. The pitching and heaving motions of the ship are transmitted to the aircraft by a realistic simulation of the landing gear.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Perez Y Perez, L., "A Time Domain Solution to the Motions of a Steered Ship in Waves," California University, Berkeley; Department of Naval Architecture, Report No. CG-D-19-73, November 1972.	Displacement	Ship Motions	The problem of ship motions in waves is formulated in the time domain by means of a convolution integral which relates the ship motion response to arbitrary exciting forces, under assumption that the response is linear. The convolution integral is evaluated numerically to obtain the ship motions at discrete intervals of time. Frequency independent nonlinearities of arbitrary form are incorporated into the model by considering them as part of the arbitrary exciting forces. Nonlinearities with time lag, such as those arising from rudder motions, are particularly amenable to this treatment. Nonlinearities that are functions of the instantaneous motions of the ship are approximated by continuously extrapolating the ship motions. Thus one is able to include frequency-dependent linear force terms in what amounts to a stepwise solution of the nonlinear equation of motion, a capability not available in the conventional direct numerical integration techniques exemplified by, e.g., runge-kutta.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Kaplan, P., Raff, A. I., "Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Loads," Oceanics, Incorporated, Ship Structure Committee, Report No. SSC-229, July 1972.	Displacement	Motions Prediction	An analytical method for the determination of conventional merchant ship motions and wave-induced moments in a seaway is developed. Both vertical and lateral plane motions and loads are considered for a ship travelling at any short crested seas. Strip theory is used and each ship hull cross-section is assumed to be of Lewis form shape for the purpose of calculating hydrodynamic added mass and damping forces in vertical, lateral and rolling oscillation modes. The coupled equations of motion are linear, and the superposition principal is used for statistical response calculations in irregular seas. All three primary ship hull loadings are determined, i.e. vertical bending, lateral bending and torsional moments, as well as shear forces, at any point along the length, with these responses only representing the low frequency slowly varying wave loads directly induced by the waves. A computer program that carries out the calculations was developed, and is fully documented separately. The results of the method are evaluated by comparison with a large body of model test data. The comparison extends over a wide range of ship speeds, wave angles, wave lengths, and loading conditions, as well as hull forms. The agreement between the calculations and experimental data is generally very good. Thus, a method is available for use in the

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			rational design of the ship hull main girder structure.
Romero, E., "Mathematical Models and Computer Solution for the Equations of Motion of Surface Ships and Submarines, in Six Degrees of Freedom," Naval Postgraduate School, June 1972.	Displacement	Motions Prediction	From the standard equations of motion, mathematical models are developed and standardized for simulation in analog or digital computers. A study is done of simulation techniques as applied to the mathematical models. A new technique for simulation of very complex systems of equations including nonlinearities is developed. The model can be used in control studies. Digital simulations of the dynamics of the semisubmerged ship and a submarine in six degrees of freedom are done. This latter with all the nonlinearities and cross-coupling terms included.
Lewison, G.R.G., "Simulation of the Roll Motion of a Stabilized Ship," Nat. Phys. Lab., Teddington, England, Report Ship No. 161, March 1972.	Displacement	Motions Prediction	This report describes a computer program that allows the roll motion of a ship in irregular seas to be studied. The ship is assumed to have a roll stabilizer in the form of a passive tank, and the effects of sway motion as well as of non-linear damping and restoring moments are considered. The output is a graphical display of both unstabilized and stabilized roll motion so that the effectiveness of any given stabilizer design may be seen. The statistics of the motion may be calculated with the aid of an auxiliary program.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Raff, A.I., "Program SCORES - Ship Structural Response in Waves," U.S. Coast Guard, Ship Structures Committee Report No. SSC-230, 1972.	Displacement	Motions Prediction	Information necessary for the use of the SCORES digital computer program is given. This program calculates both the vertical and lateral plane motions and applied loads of a ship in waves. Strip theory is used and each ship hull cross-section is assumed to be of Lewis form for the purpose of calculating hydrodynamic forces. The ship can be at any heading, relative to the wave direction. Both regular and irregular wave results can be obtained, including short crested seas (directional wave spectrum). All three primary ship hull loadings are computer, i.e., vertical bending, lateral bending and torsional moments.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Dalzell, J.F., "A Study of the Distribution of Non-Linear Ship Rolling in a Seaway," Stevens Institute of Technology, Davidson Laboratory, Report No. SIT-DL-71-1562, September 1971.	Displacement	Motions Prediction	This report describes the methods and results of a digital computer simulation of a non-linear random process analogous to one of the simpler analytical models for ship rolling.
Escalona, J.R., "The Anti-Roll Stabilization of Ships," Naval Postgraduate School, Monterrey, California June 1971.	Displacement	Motions Prediction	The theory of roll stabilization of ships is presented in the context of modern control theory. The most common systems used to reduce roll are described, and the principal equations are formulated. A general approach for the analysis of roll stabilizers is developed and applied to an activated fin stabilizer system. For this approach parameter plane techniques were applied, and the system was simulated in a digital computer. A system is proposed which is intended to improve the performance of passive tank stabilizers.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Chenault, D.W., II, "Motion of a Ship at the Free Surface," Naval Postgraduate School, Monterrey, California, December 1970.	Displacement	Motions Prediction	Forced harmonic heaving motion of a ship at the free surface of an inviscid incompressible fluid is analyzed. Added mass and damping are determined using finite element techniques. Isoparametric elements with curved boundaries allow accurate representation of the hull shape. A computer program is developed and results are found to agree closely with previously obtained theoretical and experimental results.
Bales, N.K., and Cummins, W.E., "The Influence of Hull Form on Seakeeping," The Society of Naval Architects and Marine Engineers, Presented at the Annual Meeting, November 1970.	Displacement	Motions Prediction	This program is a "standard series" approach to the trend determination problem. It involves construction of an extensive data base and interpolation over a selected subset thereof for each specific problem. Application is made to single-screw cargo hulls without large bulbs operating in directly ahead seas. The resulting predictions are found to be satisfactory.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Loukakis, T.A., "Computer Aided Prediction of Seakeeping Performance in Ship Design," MIT, Department of Naval Architecture and Marine Engineering, Report No. 70-3, August 1970	Displacement	Motions Predictions	A computerized procedure is presented for the prediction of seakeeping performance in regular waves and in a seaway. Predictions are made for a given hull form or a series 60 hull generated by the procedure. The results include: absolute and relative motions, velocities and accelerations along the hull, longitudinal shearing forces and bending moments along the hull, mean added resistance, seakeeping events, e.g., deck wetness, slamming, etc, calm water powering, calm water shearing forces and bending moments. The procedure is documented with all the necessary theoretical information, examples, descriptions of the input data and computer program listings. The program is written in FORTRAN IV computer language for an IBM/360-65 computer.
Frank, W., Salvesen, N., "The Frank Close-Fit Ship-Motion Computer Program," NSRDC Report No. 3289, June 1970.	Displacement	Motions Predictions	This program computes pitch and heave motions for ships in regular and irregular head waves. It also computes absolute and relative vertical displacement, velocity, and acceleration at any point along the length of the ship.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Kaplan, P., Sargent, T.P., Raff, A.I., "An Investigation of the Utility of Computer Simulation to Predict Ship Structural Response in Waves," Ship Structure Committee, National Academy of Sciences, Report No. SSC-197, June 1969.	Displacement	Motions Prediction/ Skimming	Methods of computer simulation of ship structural response in waves are described, with emphasis given to the slowly varying bending moments due to waves and to slamming responses. Analog, digital, and hybrid computer systems are analyzed, and results obtained by use of the most efficient computational procedures for each type of structural response. The vertical and lateral bending moments due to waves are determined by use of a digital computer, and sample computations illustrated for determining frequency domain outputs. Time history outputs of vertical bending moments due to nonlinear slamming are obtained using a modal model of the ship structural dynamic representation, together with time histories of the wave-induced vertical bending moment due to the same wave system. The capabilities of various computer systems to obtain the required responses, the form of the mathematical model appropriate for computational means, and the time requirements for carrying out the operations are also presented. The rapid assessment of spectral responses and their related statistical properties by means of digital computation, together with time history responses at rates faster than real time, provides a useful tool for determining many aspects of ship structural response characteristics by means of computer simulation.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Salvesen, N., "Manual Ship Motion Computer Program ZK11," DTMB Hydromechanics Laboratory, Technical Note No. 65, January 1967.	Displacement	Motions Prediction	The program computes pitch and heave amplitudes and their phase angles in regular head and following waves. The linearized strip theory by Korvin-Kroukivsky (1957) with forward-speed effects as derived by E.O. Tuck (1966) is used. Furthermore, it computes the bending moment and the shear force and also several statistical responses in irregular seas, applying a Neumann energy spectrum. Ship sections are represented by Lewis forms resulting in a minimum amount of input data and a very short computation time.
Andrews, J.N., and Chuang, Sheng-Lun, "Seaworthiness Analog Computer," DTMB Report No. 1829, August 1965.	Displacement	Motions Prediction	A Seaworthiness Analog Computer has been developed to simulate the structural response of the ship hull to the hydrodynamic forces of the sea, and computations have been made to verify the feasibility, flexibility, and capability of the computer. The analog computer consists of a sea generator to generate sinusoidal seas, discrete wave trains, or random seas; a ship analog divided into 20 equally spaced segments which represent the mass-elastic characteristics along the ship; and a hydrodynamic force generator divided into nine sections, four of which are capable of introducing nonlinear hydrodynamic forces. The output of the ship analog is fed back into the hydrodynamic force generator to produce the dynamic interaction between

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			the ship and the sea. Computations made to determine the response of an aircraft carrier to a specific wave train agreed very well with the actual measurements made on the ship. It is believed, therefore, that the computer can be of great assistance in ship structure design.
Goodrich, G.J., and Downey, J.M., "The Use of a Computer in Ship Hydrodynamic and Hydrostatic Calculations," National Physical Laboratory, Ship Division, Report No. SH R17/60, August 1960.	Displacement	Motions Prediction	Computation of Bonjean and hydrostatic curves - G.J. Goodrich and J.M. Downey, Calculation of static pitch and heave of a ship (with or without Smith effect) - G.J. Goodrich and J.M. Downey, Computation of forces and moments acting on a ship in a regular seaway - G.J. Goodrich and J.M. Downey, Computation of coefficients used in equations of motion (coupled pitch and heave) - G.J. Goodrich and J.M. Downey, Solution of equations of Motion - G.J. Goodrich and J.M. Downey.
"Simulation of the Sea and Analog Computation of the Forces on a Ship in Waves," Reed Research Inc., November 1959.	Displacement	Motions Prediction	The David Taylor Model Basin has for some time used a passive electrical network analogy to simulate the mass and elastic properties of a ship's hull. By exciting the analog at different frequencies the natural frequencies and normal modes of flexural vibration of the hull are determined. The Model Basin wishes to use the hull

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			bration analog to study the motion and whipping vibration of a ship in waves. We have derived mathematical expressions for the forces exerted by the sea on a ship and devised analog computer circuits to simulate this action. Thus the hull analog can be driven to simulate the ship's response.
Moran, D., "Added Resistance of Ship in Head Seas: A Computer Program Users Manual," NSRDC Ship Performance Department, Technical Note No. 239, January 1973	Displacement	Added Resistance	Three techniques appropriate for the determination of the added resistance encountered by a ship moving in a wave field are outlined. Computer programs employing these techniques are presented. The operation and use of the programs are described in several illustrative examples. The three approaches give different values of added resistance and the programs should, therefore, be used with caution. The programs represent the present state-of-the art in added-drag prediction.
Loukakis, T.A., "Theoretical Evaluation of Ship Added Resistance in Waves," MIT, Department of Ocean Engineering, Report No. 72-17, August 1972.	Displacement	Added Resistance	Theoretical added resistance calculations for a ship in regular waves were performed by Maruo's theory. The overall results were applicable to ships with cruiser stern. The theory was applied to 72 hull forms with parametric variations of their principal characteristics. For a test case Maruo's theory yielded similar results to Gerritsma's theory. Theoretical predictions of ship

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			motions by *different* strip theories were found to affect the added resistance calculations. A computer program for Maruo's theory is presented. An additional computer program allows the determination of added resistance in a seaway from the presented results in regular waves.
Beck, Robert F., "The Added Resistance of Ships in Waves," Massachusetts Institute of Technology, Department of Naval Architecture and Marine Engineering, Report No. 67-9, June 1967.	Displacement	Added Resistance	In this work Marou's linearised theory of the added resistance of a ship in regular waves is examined and placed in a form which will allow evaluation of the added resistance for any ship type. A computer program has been written to carry out these calculations.
Hershey, A.V., "Computing Programs for Ship Waves," U.S. Naval Proving Ground, NPG Report No. 1585, April 1958.	Displacement	Added Resistance	It is planned to calculate the wave resistance of a ship of finite bre^dth in water of finite depth in two stages. In the first stage, which is summarized in this report, there will be two phases. In Phase No. 1, Fourier amplitudes in integrals of the Havelock type will be expressed by polynomial approximations, while in Phase No. 2, quadrilateral elements of the ship shape will be mapped on a plane square.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Gray, H.P., Allen, R. G., Jones R.R., "Prediction of Three-Dimensional Pressure Distributions on V-Shaped Prismatic Wedges During Impact or Planning," NSRDC Report No. 3795, February 1972.	Displacement	Slamming	A computer program has been developed which calculates the water-pressure distribution on V-bottom prismatic wedges during impact or planing. The method of computation is based on previously published semi-empirical procedures with several modifications that facilitate programming and result in close correlation to recently published experimental data. The prismatic wedge may have any positive value of trim, deadrise angle, and wetted length. The pressure distribution for the entire hull or any given section of the hull may be calculated in specified increments by using the appropriate input data. Results obtained from the program are in reasonable agreement with certain published experimental planing data.
Chuang, Sheng-Lun, "Theoretical Investigation of Dynamic Interaction Between Ship Bottom and Fluid During Slamming," NSRDC Report No. 2403 December 1967.	Displacement	Slamming	A FORTRAN IV program for computing the elastic response of a two-dimensional plate under impact load.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Ochi, M.K., Motter, L.E., Journal of Ship Research; Society of Naval Architects and Marine Engineers, Vol. 13, No. 2.	Displacement	Slamming	A method for predicting the magnitude of the largest (extreme value of) impact pressure associated with ship slamming was developed by applying order statistics. Formulas were obtained to estimate (a) the most probably value of the extreme pressure, and (b) the magnitude of pressure having a preassigned probability of being exceeded in n observations. These formulas were programmed for the IBM 7090 computer. This program may be used together with existing ship motion prediction programs so that the seaworthiness characteristics of a ship can be predicted in the design stage.
Kaplan, P., and Sargent, T.P., "Further Studies of Computer Simulation of Slamming and other Wave-Induced Vibratory Structural Loadings on Ships in Waves," U.S. Coast Guard, Ship Structure Committee, Report No. SSC-231.	Displacement	Slamming	The present report describes the results of analytical modeling and computer-simulation techniques for determining the vibratory structural loads, as represented by the vertical bending moments, which may be associated with bottom-impact slamming, bow-flare slamming ('whipping'), and springing. Only head seas are considered, and the outputs are obtained in the form of time histories due to the nature of the non-linearities with the non-stationary properties associated with the slamming phenomenon. Springing is considered to be linear and statistically stationary, and the output in either time history or spectral form is

TABLE 1

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			possible. Time history simulation of the slowly-varying direct wave-induced vertical bending moment is also provided, so that the relations between the constituents of the total vertical bending moment are made clear. All the results were obtained by use of a large general-purpose high-speed digital computer with programs written in FORTAN. In this way the output data are provided at rates some 80 times faster than real time.
Brown, S.H., Alvestad, R., "Hybrid Computer Simulation of Maneuvering During Underway Replenishment," International Shipbuilding Progress; International Periodical Press, September 1974, Vol. 21, No. 241.	Displacement	Maneuvering	This paper describes a hybrid computer simulation of ship maneuvering during underway-replenishment operations. Two identical mariner class merchant ships are used in this study. However, the simulation is easily adapted to any class of surface ship. The ships dynamics are simulated on an EAI680 analog computer, while the nonlinear interaction forces are generated on a PDR-15 (DEC) digital computer.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Gynther, J.W., Sheets, H.E., "Analytical Recreation of Vessel Maneuverability Casualties," Marine Technology Society, September 1974.	Displacement	Maneuvering	This paper describes the ex post facto use of a computerized ship maneuvering model in recreating and analyzing collision and grounding casualties. The computer model utilizes the vessel characteristics plus a spatially variable current constant wind to calculate the vessel's trajectory. A topographical water depth array also is inputted for shallow water effects and the grounding condition. A comparison of "partial" and "complete" simulations are discussed with regard to controlling this type of computer model. An actual grounding incident is used to illustrate the entire casualty re-creation concept and the potential of this tool in analyzing vessel maneuvering casualties.
Aguayo, E., "Course Keeping with Automatic Control," Naval Postgraduate School; Monterrey California, December 1973.	Displacement	Maneuvering	A ship in steering is considered as a physical mechanism that is forced by a rudder movement to produce a response. Emphasis is placed upon the relation between the forcing and the response, leaving aside any detailed consideration of the forces concerned. Course-keeping with automatic control techniques is studied following this concept. Computer programs are developed to simulate different conditions. Interpretation of the results is made to evaluate the different methods used.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Park, D.S., "Dynamical Stability and Maneuverability of Dynamically Unstable Ships," Naval Postgraduate School; Monterrey, California, December 1973.	Displacement	Maneuvering	The factors affecting the stability and the maneuverability of a dynamically unstable ship were studied using the linear and non-linear equations of the motion of the ship. The DSL/360 language was used to simulate the dynamics and to study both unstable motions and standard maneuvers.
Mori, M., Tanaka, M., "Simulation Program for Maneuverability of Ship and its Application," Ishikawajima & Harimu Heavy Industries Co. Ltd., Tokyo, Japan, Vol. 13, No. 5, September 1973.	Displacement	Maneuvering	In designing a new ship correct predictions of prospective maneuverability are most indispensable. Especially in the case of Very Large Crude Carrier prior clarification of the effects of hull and rudder configurations on maneuverability is a prerequisite for determining the principal dimensions. In order to meet these requirements, a simulation program for a digital computer was developed by the authors. By solving the equations of horizontal plane motion with hydrodynamic derivatives estimated from input data on hull, rudder and propeller, the computer program makes predictions of non-linear ship motion which initiates various rudder actions. It is, of course, possible to use those derivatives obtained from model tests, in order to improve the accuracy of predictions. This program can simulate the performance of such standard maneuvers as turning test, zig-zag(Z)

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			tests including modified Z maneuver and new course tests. It can also simulate the characteristics of course keeping and course changing by autopilot control in a seaway, by adding a pseudo random noise signal to yaw moment and sway forces, corresponding to such sea disturbances as wind and waves.
Galanis, M., "Simulation Studies for Replenishment at Sea Operation," Naval Post-Graduate School, Monterrey, California, September 1973.	Displacement	Maneuvering	The study investigates the maneuvering of ships involved in the replenishment at sea operation under calm water conditions. Two sets of linear differential equations of motion of a ship in three degrees of freedom are implemented for an analog-digital simulation (hybrid operation). Mainly a two phase hybrid simulation is carried out.
Mori, M., Tanaka, M., Mizaguchi, S., "Simulation Program for Maneuverability of Ship and its Application," Ishikawajima-Harima Eng. Rev. (Japan), Vol. 13, No. 5, September 1973. (In Japanese).	Displacement	Maneuvering	By solving the equations of horizontal plane motion with hydrodynamic derivatives estimated from input data on hull, rudder and propeller, the computer program makes predictions of non-linear ship motion which initiates various rudder actions. It is, of course, possible to use those derivatives obtained from model tests, in order to improve the accuracy of predictions. This program can simulate the performance of such standard maneuvers as turning test, zig-zag (Z) tests including modified Z maneuver and

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			new course test. It can also simulate the characteristics of course keeping and course changing by autopilot control in a seaway, by adding a pseudo random noise signal to yaw moment and sway forces, corresponding to such sea disturbances as wind and waves.
Mori, M., Tanaka, M., "Ship Maneuverability Simulation Program," North Holland Publishing Company, No. II-5, August 1973.	Displacement	Maneuvering	A new technique for assessing maneuverability early in the design stage is the ship maneuverability computer simulation program. This computer program embraces all present sea trial tests except stopping. Computer simulation, model tests and sea trials show good agreement.
Kerns, K.H., Cooper, R.S., "A Microcomputer Solution to Maneuvering Board Problems," Naval Postgraduate School, Monterrey, California, June 1973.	Displacement	Maneuvering	A special-purpose digital computer has been developed using the new MOS LSI Micro-processor technology. The primary goal of this work was to solve a fairly complicated task using a minimal amount of random logic and limited development time. This computing system solves ships' maneuvering board problems including the determination of course, speed, and closest point of approach of other ships. Ten contacts can be tracked simultaneously.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Milkowski, B., and Rybczynski, M., "Mathematical Model of Ship Turning Circle in Calm Water (in Polish)," Budownictwo Okretowe, No. 1, January 1973.	Displacement	Maneuvering	A method of hybrid modeling of a ship's turning circle is presented. The hybrid technique, which employs a simplified system of dynamic turning-circle equations, provides results with an accuracy of ± 10% of measured values obtained during actual ship trials. Advantages and application possibilities of the technique are discussed. The paper includes the system of equations used, the hybrid-program flow chart, and some graphed results of a turning circle modeled.
Ozdemir, B., "Simulation of Low Speed Forward Ship Motion in the Wind," Naval Post-graduate School, Monterrey, California December 1972.	Displacement	Maneuvering	The objective of the study was to examine the relationship between forward ship motion and the effects of aerodynamic and hydrodynamic disturbances on motions in the horizontal plane. It includes course control and stability analysis for the unsteered and steered cases (manual and automatic) using several sets of operating conditions. Hydrodynamic and aerodynamic effects are considered to be functions of hull motion, rudder (steered cases), propeller and wind effects ratio. A dimensionless mathematical model has been developed and solved with respect to ship axes.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Eda, H., "Ship Maneuvering Motion Prediction for a Vessel Safety Model," Stevens Institute of Technology; Davidson Laboratory, Technical Report No. SIT-DL-72-1625, August 1972.	Displacement	Maneuvering	A ship maneuvering motion procedure has been developed to be used in a vessel safety model utilizing experimental data obtained in free-running model tests. Ship Trajectories in terms of steady turning rate, advance, and transfer can be determined as functions of ship length, draft, beam, rudder area, rudder angle, and water depth. Furthermore, speed reduction due to turning can be computed as a function of ship hull parameters and turning rate. The effectiveness of the harbor navigation model is indicated by fairly good agreement between predictions and actual data points. Basic equations of ship maneuvering motion and a summary of existing hydrodynamic data in this area are also presented.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			includes a summary of the time each ship spends in each state. The summary can be produced daily, quarterly, or for the entire simulation time of the run, which may be up to six years.
Patell, J.M., "A Digital Model for Ship Maneuvering for Use in Traffic Control Simulation," MIT, Department of Ocean Engineering, May 1972.	Displacement	Maneuvering	A digital model for simulating the hydrodynamic and machinery response of a vessel while maneuvering is developed and tested for a variety of vessel forms. A set of four basic maneuvers is simulated for each vessel, and plots of predicted trajectory are produced and checked against model tests and/or ship trials for each of six ships. The model is constructed from three differential equations of motion, one differential equation of engine response, and three supporting equations. The coefficients of these equations are derived or approximated from a very minimal input description of the vessel. Finite depth effects have been omitted in this iteration. The experimental results indicate that the model accurately distinguishes between dynamically stable and unstable ships (spiral test), and yields predicted trajectories which differ from trial results by 5% to 20%, depending on screw and rudder characteristics. Improved accuracy can be obtained by further refinement of the coefficient approximations. The

TABLE 1

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			input provided by this model for the complete traffic control simulation is presented in a diagram of the full traffic simulation model.
Day, W.G., and Lin, W.C., "Tactical Diameter Prediction for Twin Screw Destroyers," NSRDC SPD Evaluation Report No. C-455-H-01, April 1972.	Displacement	Maneuvering	This is used to predict turning characteristics (diameter of turning circle). The characteristics are a function of 10 parameters, 8 of ship and rudder geometry, 2 of operating variable (speed and rudder angle).
Kenan, G., "Collision Avoidance Between Surface Ships at Short Ranges," Society of Naval Architects and Marine Engineers, March 1972.	Displacement	Maneuvering	Encounters at short ranges between mariner class ships have been simulated on the computer. Trajectories were obtained using non-linear maneuverability theory and the actual dimensions of the ships were included. Initial ranges and relative bearings leading to an avoidable collision were determined for various speeds under different restraints. The effect of coordinated maneuvers was also investigated.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Eda, H., "Directional Stability and Control of Ships in Restricted Channels," Society of Naval Architects and Marine Engineers, November 1971.	Displacement	Maneuvering	The dynamic behavior of ships in various channels is examined to develop a guideline to the design and operation of the ship-waterway system, with an emphasis placed on a large full-form ship. Realistic modeling of ship motions has been achieved on a digital computer utilizing hydrodynamic data which were determined in captive model tests, with inclusion of non-linear terms. A series of digital simulations and eigenvalue analyses have been made to evaluate ship performance in channels with a wide range of parameter variations in channel width, water depth, and control system (or helmsman) characteristics. Consistent results are obtained from two different computational procedures, digital simulations and eigenvalue analyses. Results of directional stability, off-centerline course operation, and squat calculations are applied to indicate the relationship between channel dimensions and acceptable ship size. Ship motions during meeting and passing in a canal also have been examined in digital simulations. The predicted ship trajectory compares favorably with full-scale experience of canal pilots.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Kettenis, D.L., "On the Mathematical Description of Ship Maneuvering," Netherlands Ship Model Basin, Report No. NSMB-375, August 1971.	Displacement	Maneuvering	In the N.S.M.B. simulator the real time response of the ship on commands from the wheelhouse is calculated by a computer and made visible by projection on a circular screen around the wheelhouse. The forces and moments acting on the ship are derived from tests with a model of the ship to be simulated. With a model matching method the unknown coefficients in the mathematical model are determined. The resulting characteristics are programmed on a hybrid computer. The computer gets its commands from the wheelhouse of the maneuvering simulator. The computed movements of the ship are, through a projection system, displayed on the circular screen.
Padgett, Stephen J., "Computer Program for a Mooring and Docking Trainer," NSRDC SPD T&E Report No. 382-H-03, June 1971.	Displacement	Maneuvering	The purpose of this report is to document the digital-computer program which was written for use in the computer-simulation studies as part of the development of training simulators for naval ships in mooring and docking operations.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Van Manen, J.D., Hooft, J.P., "Three Dimensional Simulator for Maneuvering of Surface Ships," International Shipbuilding Progress; International Periodical Press, Vol. 17, No. 194, October 1970.	Displacement	Maneuvering	This paper presents a description of the Netherlands ship model basins' maneuvering and steering simulator which consists of a wheelhouse, and acclimatization room, a visual display and a hybrid computer. Also discussed are the human aspects of ship maneuvering and simulation, nautical aspects of ship handling in simulation and the preparation of software to simulate the maneuverability of super tankers.
Sargent, T.P., Kaplan, P., "System Identification of Surface Ship Dynamics," Oceanics Incorporated, April 1970.	Displacement	Maneuvering	The feasibility of applying a newtonian system identification technique to a non-linear three degree of freedom system of equations describing the steering and maneuvering of a surface ship is investigated. The input to the system identification program is provided by both analog and digital computer generated maneuvers. The dominant eleven coefficients, treated as unknowns, are sought using exact and noisy data, and the utility and limitations of the method are described.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Rubis, C.J., "Braking and Reversing Ship Dynamics," Naval Engineers Journal, American Society of Naval Engineers, Inc., Vol. 82, No. 1, February 1970.	Displacement	Maneuvering	The results of a ship braking and reversing dynamics study are presented for a CARGO single screw CARGO ship with a fixed pitch propeller and a reversing reduction gear. A digital computer simulation was used to calculate the major ship and propulsion plant parameters for various propulsion maneuvers including coast down, braking, and reversing. A computer technique for solving the ship propulsion dynamics equations is described, the equations for clutching and braking are derived, and the results of braking and reversing maneuvers for speeds greater than 30 knots are shown in detail for a hypothetical study ship.
Brug, J.B., Van Den, Wagenaar, W.A., "Experimental Simulator for the Maneuvering of Surface Ships," International Shipbuilding Progress; International Periodical Press, Vol. 16, No. 180, August 1969.	Displacement	Maneuvering	The simulator consists of a wheelhouse having a wheel, a rudder angle indicator and a compass, an analog computer and a point light source projector. The simulators performance was evaluated by professional shipofficers, and pilots and used for several investigations, including the transfer functions of helmsmen and training studies.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Sikes, T W., "A Model for Simulating Underway Replenishment Ship Operations," The RAND Corporation, Memorandum RM-5517-ISA, January 1968.	Displacement	Maneuvering	The model simulates the operation of underway replenishment ships, both oilers and ammunition ships, supporting Navy Task forces at sea under various assumptions about operating radius from base, ships' characteristics, and intensity of combat activities.
Eda, H., "Steering Control of Ships in Waves," Stevens Institute of Technology Report No. SIT-DL-69-1205, June 1967.	Displacement	Maneuvering	The stability and oscillatory motions of ships (automatically steered and unsteered) in the horizontal plane were examined on a digital computer for the case of regular following seas.
Eda, H., Crane, C.L., Jr., "Research on Ship Controllability Part 4. Non-Linear Prediction of Steering Performance of Series 60 Models," Stevens Institute of Technology, Report No. SIT-DL-69-1039, June 1967.	Displacement	Maneuvering	A digital computer was used to make non-linear predictions of ship response to rudder action and these predictions are compared, in the report, with trajectories for a free running model. They are found to correlate satisfactorily. On the basis of this correlation and by means of the same computation, variations of ship maneuvering motions with changes in ship configuration are examined. The ship configuration parameters which are varied include rudder size, block coefficient, draft, breadth, profile, and section shape. The relationship between maneuvering response and rudder rate is

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			examined, using non-linear computation, to obtain a basis for determining optimum rudder rate for ships of different speed and size. Computed results show that the minimum rudder rate presently allowed by the rules and regulations is adequate for ocean trading ships of ordinary size and speed; however, this adequate rudder rate could be lower for very large, relatively slow ships, such as supertankers.
Strom-Tejsen, J., "A Digital Computer Technique for Prediction of Standard Maneuvers of Surface Ships," DTMB Report No. 2130, December 1965.	Displacement	Maneuvering	This program predicts steering and maneuvering qualities. The hydrodynamic force and moment derivations representing the input can be obtained from present captive model testing techniques. Any motion of a surface ship including tight maneuvers and loop phenomenon recognized in the spiral maneuver for a directionally unstable ship are predictable.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Bentkowsky, J., "Ship's Bridge Control Console System," Sperry Piedmont Company, February 1963.	Displacement	Maneuvering	Report describes a ship's bridge control console system design sufficiently flexible for use in all ships and trades and concluded to be the optimum combination of equipment needed to carry out the ship's bridge functions in a safe, practical and economically realistic fashion. Details are given for the function, operation, and principal of the ship motion predictor, an experimental equipment developed for this prototype program. The predictor is a device for detecting incipiently dangerous conditions caused by heavy seas, predicting an optimum course of action, and evaluating the result of the corrective action without a trial and error period. The console is also discussed in terms of human engineering principles and operator performance capability.
Thomas, G.O., "Documentation of the Static Balance Computer Program for Obtaining the Longitudinal Strength of a Ship Hull," DTMB Report No. 2272, January 1967.	Displacement		This report describes the computer programs (YP04), (YP05) written to extend the static balance method of calculating shear and bending moment responses to include a wide range of wave heights, lengths, and positions with respect to amidships for a ship vertically balanced in head-on trochoidal waves. The program has the option of including or omitting the Smith correction, and the final data may be presented in either tabular or graphical form.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Compiled by Kukk, A., "Input Formats to 7090 Computer Programs Currently used in Vibration Calculations," NSRDC Report No. 2501, June 1968.	Displacement	Vibrations	A compilation has been made of input formats to IBM 7090 computer programs which are currently used in vibration calculations. These programs are: 1. Structural Analysis by Digital Simulation of Analog Methods (SADSAM III) 2. General Bending Response Code 1 (GBRC1) 3. General Bending Response Code 2 (GBRC2) 4. General Bending Response Program (GBRP) 5. Program for Propeller Forces Derived from Model Wake Survey This report will be helpful in familiarizing people with the forms to be used in preparing data for the various computer programs.
Cuthill, E.H., and Henderson, F.M., "Description and Usage of General Bending Response Code 1 (GBRC1)," DTMB Report No. 1925, July 1965.	Displacement	Vibrations	Generalized Bending Response Code 1 (GBRC1) is a digital-computer code for solving the system of finite-difference equations which approximate the boundary-value problem representing the steady-state motion of a vibrating beam-spring system such as a ship hull in bending. In particular, this program can be used to calculate the response of beams and beam-spring systems to specified simple-harmonic driving forces and/or moments.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Polachek, Harry, "Calculation of Transient Excitation of Ship Hulls by Finite Difference Methods," DTMB Report No. 1120, July 1957.	Displacement	Vibrations	A system of finite difference equations based on the non-uniform beam theory is developed for use in the calculation of the response of a ship hull to transient forces. The use of this method lends itself to the solution of a wide class of problems related to the structural design of vessel hulls or other structures subject to transient forces. The solution has been programmed and carried out on the Bureau of Ships UNIVAC System, Applied Mathematics Laboratory, David Taylor Model Basin.
Adams, Emily J., "The Steady-State Response of a Ship Hull to a Simple Harmonic Driving Force Computed by a Digital Process," DTMB Report No. 715, May 1950.	Displacement	Vibrations	A numerical method of finding the steady-state response of the hull of a ship to sinusoidal driving force is described.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Liang, S.W., Botting, H.M., "Computer Program Documentation Program PROVIB Design and Vibration Analysis of a Ship Propulsion System, Part One, Designers' Manual," NSRDC Report No. 3172-1, October 1969.	Displacement	Propulsion	PROVIB is a general purpose ship design computer program for design and analysis of a ship propulsion system. Its functions include selection of basic propeller parameters, design of shafting, design of reduction gear including a geometric check, and analysis of the longitudinal, torsional, and vertical vibrational characteristics of the propulsion system. The program is configured to execute design computations for propulsion systems, either for whole systems or for the individual components which comprise the systems.
Schmitke, R.T., "Prediction of Pitch and Heave Motions of Hullborne Hydrofoil Vessels," Defence Research Establishment Atlantic Dartmouth, Report No. DREA-74-2, January 1974.	Hydrofoil	Motions Prediction	Computer programs have been developed to predict the pitch and heave motions of hullborne hydrofoil vessels in head seas. Good agreement between theory and experiment has been obtained with model test data for AG(EH) plainview and with full-scale trials results of HMCS BRAS D'OR.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Jamieson, J.J., "Mathematical Model Report, Volume II, Equations and Methods for Simulation of Hull Lift, Drag, and Pitch Moment," U.S. Naval Training Device Center August 1965.	Hydrofoil	Motions Prediction	This report presents the results of a study to determine the six-degree-of-freedom equations of motion for hydrofoil craft and the equations for the description of realistic seas.
Ogilvie, T.F., "The Theoretical Prediction of the Longitudinal Motions of Hydrofoil Craft," DTMB Report No. 1138, November 1958.	Hydrofoil	Motions Prediction	The non-linear theory of Weinblum for predicting the longitudinal response of hydrofoil craft in waves is modified, and the results of analog computations based on this theory are presented for comparison with available experimental data.
Leehey, CDR P, USN, Steele, J.M., Jr., "Experimental and Theoretical Studies of Hydrofoil Configurations in Regular Waves," DTMB Report No. 1140, October 1957.	Hydrofoil	Motions Prediction	The theoretical responses were computed from the equations given by Weinblum in "Approximate Theory of Heaving and Pitching of Hydrofoils in Regular Shallow Waves," TMB Report C-479.

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AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Schmitke, R.T., "A Computer Simulation of the Performance and Dynamics HCMS BRAS D'OR (FHE-400)," Canadian Aeronautics and Space Journal, Vol. 17, No. 3, March 1971.	Hydrofoil	Performance/ Dynamics	A computer simulation is described of the performance and dynamics of the surface-piercing hydrofoil ship HMCS BRAS D'OR (FHE-400). Comparison of simulated ship performance with data from calm water trials shows encouraging agreement.
Moore, W.L., "Calculation of the Lift and Drag of Hydrofoils, Struts, and Pods in Various Configurations," NSRDC Report No. 383-H-01, April 1970.	Hydrofoil	Lift Drag	This report describes a FORTRAN IV computer program which calculates the lift and drag of a hydrofoil-strut-pod configuration.
Giesing, J.P., "Two-Dimensional Potential Flow Theory for Multiple Bodies in Small-Amplitude Motion (Manual for Computer Program 67 MA)," McDonnell Douglas Corp., Report No. DAC-67028 Vol. II, April 1969.	Hydrofoil	Potential Flow about Foils	A method has been developed for calculating the two-dimensional potential flow about two foils of arbitrary shape and at arbitrary incidence undergoing small-amplitude simple-harmonic motions. The two foils may be vibrating at two different frequencies. The computer program described (67MA) also can calculate steady streamlines as an option.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Caspar, J.R., "Divergence Analysis of Swept Hydrofoils - Computer Program (SWDIVRG)," NSRDC Report No. 4245, April 1974.	Hydrofoil		A systematic approach is described by which divergence characteristics of swept or unswept hydrofoils may be calculated. The computer program, called SWDIVRG, developed to do the calculations, makes use of a lumped-parameter approach, resulting in a matrix solution of the system. The bending and torsional displacements at any of N stations along the hydrofoil span can be calculated at speeds less than divergence.
Furuya, Okitsugu, "Numerical Computations of Supercavitating Hydrofoils of Parabolic Shape with Wu and Wang's Exact Method," Division of Engineering and Applied Science, California Institute of Technology, Report No. E-79A.15, January 1973.	Hydrofoil		The functional iterative method applied to the non-linear exact theory by Wu and Wang has been utilized to calculate the pressure distribution on the parabolic struts with various separation points at both zero and one degree angle of attack and at zero cavitation number.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Davis, P., "Feasibility Study of a Proposed Control System on a Hydrofoil Sailboat," Toronto University Institute of Aerospace Studies, Report No. UTIAS-TN-162, March 1971.	Hydrofoil Sailboat	Control System	In the introduction, a number of hydrofoil sailing experiments were enumerated and the basic type of craft in question was defined. The need for a simple and practical control system providing stability and safety was stated. Special problems of the pitch and roll control of the hydrofoil sailboat were then discussed and the solutions of some other experimenters were shown. The static equations of equilibrium were written for a hydrofoil sailing craft. The hydrodynamic forces for a particular set and configuration of foils were calculated and at the same time the aerodynamic forces for a particular sail were determined. A computer program was written to solve the equations of equilibrium under particular sets of conditions. Results were obtained for both the case when no active control system was used and also when the proposed type of control system was used. It was found that the stability of the uncontrolled case, was still not adequate in providing necessary stability.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Bandler, P.A., and Ludolph, M., "A Program to Calculate the Pressure Distribution on a Hydrofoil with Pod and Strut," Engineering Research Associates, ERA Report No. 53-6, October 1963.	Hydrofoil	Pressure on Hydrofoil	This report describes an extension of the computer program to calculate the pressures on a hydrofoil of finite span operating near the free surface. In the previous program, no account was taken of the central pod and vertical strut, which are typical of practical configurations.
Grote, R.S., "Numerical Methods and Program Description for the Inverse Problem of Linearized Fully-Cavitating, Hydrofoil Theory," The RAND Corporation, Memorandum RM-3563-PR September 1964.	Hydrofoil	Profile SHAPE	The computer routines have been devised to calculate the profile shapes for two design methods and an off-design consideration of the problem. The present report briefly discusses each of the three methods, and proceeds to detailed presentations of the corresponding subroutines. The three methods encompass the cases of shockless-entry, nose-singularity, and the off-design calculations.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Schneider, J., Bono, P., "A Study of the Dynamics of Arctic Surface Effect Vehicles. Part II. Development of the ASEV Motions Program and the Analysis of Results of Numerical Studies for Selected Craft Configurations," Oceanics, Inc., Report No. 73-101B, February 1974.	SES	Motions Prediction	This volume is Part II of a two-part final technical report on the results of vehicle dynamic studies as a part of Phase I of the ARPA arctic SEV program. The major objectives accomplished in this portion of the study were the development of the ASEV motions computer program (SEVRES), the analytical development of a stability criterion used to test arctic SEV designs, and the use of the computer program to correlate SK-5 experimental data and to perform numerical studies on selected 170 and 500 ton vehicle configurations run over various obstacles and sections of arctic terrain at various speeds.
Kaplan, P., Bentson, J., Sargent, T., "Advanced Loads and Motions Studies for Surface Effect Ship (SES) Craft. Part I. General Development of Modified Mathematical Model," Oceanics, Inc., Report No. 73-784, June 1973.	SES	Motions Prediction	A description of various modifications in the basic mathematical model describing SES craft motions is given. The primary alternation from the previous model involves a modified representation of lateral hydrodynamic forces and moments on the craft, based upon the results of model test data. Other modifications representing the seal forces, and also quantities previously neglected in earlier derivations, are also included. Comparison of predicted motions in waves with available model test data shows a sufficiently good prediction capability that validates the use of the mathematical model and the associated digital computer program. Possible

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			limitations of the theory are presented. Together with a discussion of how such effects are overcome using particular procedures.
Silbert, M.N., Kaplan, P., "Advanced Loads and Motions Studies for Surface Effect Ship (SES) Craft. Part II. Analog Computer Simulation," Oceanics Inc., Report No. 73-98B, June 1972	SES	Motions Prediction	An analog computer representation of SES craft motion in regular head seas, for vertical plane motions, is described. The equations used are essentially linear, providing outputs for craft motions and bending moments. The stern seal dynamic model is based upon use of a constant wetted-length, which precludes the occurence of leakage at the stern, with a similar limitation at the bow seal. Comparison is given with previous digital computer results for a particular SES craft in order to validate the utility of this simplified representation. Representative program diagrams for use of an analog computer as a simulation tool are presented, with the main utility of this tool expected to be in the area of heave acceleration control system analysis. In that case the analog computer simulation tool allows a more rapid assessment of control effectiveness.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Kaplan, P., Bentson, J., "Advanced Loads and Motions Studies for Surface Effect Ship (SES) Craft, Part IV. Motion and Load Characteristics of Multi-thousand Ton SES Craft," Oceanics, Inc., Report No. 73-98D, June 1973.	SES	Motions Prediction	The results of computations to determine motion and load characteristics of multi-thousand ton SES craft are presented. The different craft considered represented three different sidewall designs, including the partial length sidewall concept, and included variations in length/beam ratio and pressure/length ratio. The basic tools used for this evaluation are the large digital computer program developed in this overall study, as well as the use of the analog computer and linear frequency domain response results. Information was obtained for operation in irregular head seas as well as at oblique headings for different speed-sea state operating conditions. The most severe operating conditions, which produced the largest motions and loads, were found to be those at the lower speed-higher sea state combinations. Maneuverability studies in smooth water were also carried out for these craft.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Kaplan, P., Sargent, T.P., Bono, P.S., "Advanced Loads and Motions Studies for Surface Effect Ship (SES) Craft. Part IV. Accumulator Control for Heave Acceleration Reduction," Oceanics, Inc., Report No. 73-98F, June 1973.	SES	Motions Prediction	An analysis of the influence of an accumulator as a means of reducing heave accelerations of SES craft is presented. Equations representing the influence of the accumulator are analyzed. Together with computations carried out via frequency response analysis (linear theory) as well as analog computer simulation in order to determine the best characteristics of this type of control. Conclusions regarding the effect of accumulator frequency, damping, accumulator area and weight density, etc. in regard to the degree of acceleration reduction are presented. The influence of these accumulator characteristics on the displacement of the accumulator, in order to achieve good performance in regard to heave acceleration reduction, is also described.
Kaplan, P., Schneider, J., Silbert M., Sargent, T., "Advanced Loads and Motions Studies for Surface Effect Ship (SES) Craft. Part V. Active Control Systems for Reducing Heave Accelerations," Oceanics, Inc., June 1973.	SES	Motions Prediction	An analysis of different concepts of active control systems for reducing heave accelerations of SES craft in waves, is described. Results of computer simulation, using both analog and digital computers, are provided for the case of louver area variations as the means of control. Similarly results for control applied by means of fan blade pitch angle variation are also presented. All of these active control techniques result in reduced heave accelerations and reduced

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			structural loads, with the associated penalty of significant increases in mean and RMS power requirements relative to the uncontrolled case. The particular type of louver variation producing the most effective motion reduction is illustrated.
Cagle, L.F., "Some Performance Characteristics of the Bell 100 Ton Surface Effect Ship," Naval Post-graduate school, Monterrey, California June 1973.	SES	Motions Prediction	A computer program for simulating the performance of the 100-B surface effect ship is used to study the longitudinal motions of the ship under various wave conditions.
Robert, P., Rogers, H., Wendt, N., Hite, K., "Arctic Surface Effect Vehicle Program Vol. 4, Task 2.1.3, Vehicle Dynamics," Bell Aerospace, New Orleans, February 1973.	SES	Motions Prediction	The objective of this study was to develop model test and computer simulation techniques for predicting arctic sev dynamic response over irregular terrain and to utilize these techniques to determine sev configuration and subsystem design requirements which will provide good habitability, obstacle clearance, and stability characteristics with minimal powering and structural requirements. The simulation development involved the formulation of mathematic models for all functional elements of the arctic sev and the mechanization of these elements on the computer. The

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			simulation was modified to represent a 600-ton sev, and dynamic responses for 27 parametric variations were obtained and evaluated.
Kaplan, P., Bentson, J., Sargent, T., "A Study of Surface Effect Ship (SES) Craft Loads and Motions. Part II. Habitability and Maneuverability of SES Craft," Oceanics Inc., Report No. 71-84B, August 1971.	SES	Motions Prediction	By use of an analysis and computer program developed in the study, particular characteristics of SES craft are determined in selected modes and degrees of freedom in order to assess the vehicle performance. The aim is to determine the motions of specified SES configurations with special reference to human habitability, platform requirements for military or commercial applications, and maneuvering requirements for the on-bubble mode of operation.
Strom-Tejsen, J., "Predicting Calm Water Drag of Surface Effect Ships," NSRDC Ship Performance Department Technical Note No. 269, July 1963.	SES	Drag Prediction	This program computes the drag of a SES of the rigid-sidewall type. The program uses an iterative procedure for determining vehicle trim and distribution of list between forward and aft skis. Forces taken into consideration include wave resistance, sidewall and skis appendage drag, aerodynamic forces, and location and direction of the propulsion force.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
"500 Ton Arctic SEV Configuration Study. Volume I. Program Summary," Boeing Co., Seattle, August 1974.	SES	Maneuvering	Technical accomplishments resulting from this study are: a promising new skirt concept has been developed; a cushion system and ride quality control system have been designed which provide good ride quality and obstacle crossing capability; a maneuvering and control system and autopilot have been developed which provide good maneuvering capability on the arctic ice pack with minimal pilot effort; improved methods for calculating skirt loads, dynamics computer simulations, and a visual flight simulator to evaluate vehicle maneuvering, a relatively low risk vehicle design has been developed which meets or exceeds all major requirements.
Brooks, E.N., "Results of the Maneuvering and Control Studies Conducted for the Arctic Surface Effect Vehicle Program," NSRDC, Aviation and Surface Effects Dept. Technical Note No. TN-AL-296, February 1973.	SES	Maneuvering	This report presents significant conclusions, a user's manual for a computer program to predict the external aerodynamic characteristics of various geometry sev's, a user's manual for a three-degree-of-freedom maneuvering and control program, and abstracts of documents written during the reporting period. Primary conclusions include state-of-the-art of sev maneuvering capabilities, maneuvering forces needed for an arctic sev, how to obtain these maneuvering forces, yaw angles and craft stability and pilot aids required, results of surface contact device investigations, and recommendations for future studies.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Myers, K.R., "Turning Characteristics of the Bell 100 Ton Surface Effect Ship," Naval Post-graduate School, Monterrey, California, June 1973.	SES	Turning Characteristics	The turning characteristics of the Bell 100 ton Captured Air Bubble Surface Effect Ship (CAB/SES) are studied with the aid of the Oceanic Incorporated computer simulation. The craft's motions for straight runs, straight runs with waves and turning runs under calm water conditions, are compared with the final set of computer simulation turning maneuvers with waves involving changing speeds, wavelengths, wave amplitudes, and final rudder angles.
Ravenscroft, L.T., Jr., Mathis, P.B., "Recommended Vehicle Concepts for Waterjet Propelled High-Performance Vehicles," NSRDC, Ship Performance Department, Report No. SPD-572-01, December 1974.	SES	Powering	A rapid method is developed for estimating the overall propulsive coefficient and the drag of a vehicle concept over its operating speed range. Thus, an estimate of the shaft horsepower required as a function of speed may be obtained. Preliminary weight estimating relationships are also included so that predictions of fuel weight and payload weight may be made.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Leo, D.G., Boncal, R, XR-3 Surface Effects Ship Test Craft: A Mathematical Model and Simulation Program with Verification," Naval Postgraduate School; Monterrey, California, December 1973.	CAB	Motions Prediction	Digital computer simulation of the six degrees of freedom equations of motion for the XR-3 captive air bubble testcraft is presented.
Fishman, R.E., "External Aerodynamics of Surface Effect Vehicles," U.S. Naval Academy, Report No. USNA-TSPR-42, May 1973.	CAB	Predict Flow Phenomenon	The speeds of surface effect vehicles are of the order of one hundred knots. At these speeds aerodynamic forces become significant necessitating an understanding of the craft external aerodynamics. In order to predict external flow phenomenon about a hovercraft a discrete vortex model was applied to the problem. This model was programmed and run on a Honeywell 635 computer. A corresponding experimental model was designed, fabricated, and tested. The results of the experimental program and those obtained from the analytical computer study were then compared. It appears that the discrete vortex model is an effective means of representing the external aerodynamics of surface effect vehicles provided that sufficient computer space is available.

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Livingston, Walter H., "A Simulation Study Concerned with the Track-keeping Ability of a Typically Configured Air-Cushion Vehicle (ACV) Subjected to a Wind-gust Normal to the Track," NSRDC SPD T&E Report No. 378-H-12, January 1971.	ACV	Maneuvering	A simulation study designed for use in investigating the gross nature of the transverse control characteristics of a typically configured air cushion vehicle (ACV) has been carried out using analog computer technology exclusively.
Calkins, D., "A Study in Computer-Aided Aerospace Vehicle Design," Naval Undersea Research and Development Center, Report No. NUC-TP-112, July 1969.	Planing	Motions Prediction	An analytical study in computer-aided vehicle design is presented. The vehicle under study is the unlimited competition racing hydroplane, and the design objective is to obtain maximum lift/drag ratio in addition to adequate pitch plane stability. After discussion of the design concept, the mathematical model used to represent the aerodynamics and hydrodynamics of the configuration is developed. The mathematical model is then programmed for solution on a digital computer and an optimization study is performed. It is concluded that a tentative preliminary configuration is obtained through computer-aided design but that the complexity of the concept will require further tow tank and wind tunnel model tests.

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COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Bauman, W., "Ship Design Computer Program Hydrodynamic Design of Prismatic Planing Hulls III," NAVSEC, February 1969	Planing	Shaft HP, Longitudinal Stability Characteristics	This computer program documentation views and collates the computational procedures developed by (1) Davidson Laboratory, S.I.T., to predict the effective horsepower of prismatic planing surfaces, (2) Department of NAME, University of Michigan, to predict open-loop longitudinal stability characteristics and (3) Hydrodynamics Laboratory, NSRDC, to predict a shaft horsepower. The prismatic planing hull computations permit including a roughness allowance, a skeg and a linear change in deadrise angle with length. Only hard chine planing hulls are considered. The documentation includes a complete program listing, sample inputs and outputs, plus graphical correlation with some full scale trials data. There are five subprograms included.
Choo, K., Mansour, A., "User's Manual and Program Listing of 'Cat-5' for Catamarans," M.I.T. Ocean Engineering Report No. 73-7, June 1973	Catamaran	Motions Prediction	The program is capable of predicting motions, velocities, accelerations of catamarans moving in waves at any heading angle. The wave induced force and moment resultants on the catamaran cross-structure can also be computed. These responses can be obtained in regular waves as well as long-crested or short-crested random waves. For the latter cases, the one-parameter Pierson-Moskowitz Wave Spectrum and the two-parameter Bretschneider spectrum are used.

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COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
			In general, the basic input to the program includes the overall dimensions of the catamaran, the form and spacing of the demi-hulls, the longitudinal and transverse weight distributions, the general heading angle and the description of the sea condition by wave spectra. The output of "CAT-5" consists of the five degrees of motion velocity, acceleration responses and the wave induced forces and moments on the cross-structure.
Andrews, J.N., Davis, A.V., "A Method for Obtaining Response Amplitude Operators for Catamaran Cross Structures," NSRDC Report No. 4018, June 1973.	Catamaran	Motions Prediction	A simple static balance concept was developed for calculating vertical transverse moment and shear force, torsional moment, and transverse axial force response amplitude operators (RAO's) for catamaran cross structures
Wahab, R., Hubble, E. N., "Simplified Theoretical Methods of Predicting the Motions of a Catamaran in Waves," NSRDC Report No. 3736, January 1972.	Catamaran	Motions Prediction	A slight modification of the theory outlined by Wahab was used to develop a computer program for predicting the rolling characteristics of a catamaran in both regular and irregular seas. The program, designated RLAC, is presented

TABLE 1

COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Jones, H.D., "Catamaran Motion Predictions in Regular Waves," NSRDC Report No. 3700, January 1972.	Catamaran	Motions Prediction	Ship motion prediction theory for monohulls has been adapted, and programmed for a digital computer, to predict the heave and pitch motion characteristics of a catamaran.
Wahab, R., Hubble, E. N., "Simplified Theoretical Methods of Predicting the Motions of a Catamaran in Waves," NSRDC Report No. 3736, January 1972.	Catamaran	Motions Prediction	Simplified methods are discussed for estimating (1) the pitch and heave of catamarans in head seas based on theory which has proved successful for conventional single hulled ships, and (2) the roll of catamarans in beam seas by representing the small amount of roll as alternate heaving of the two hulls. Both prediction methods neglect interaction effects between the two hulls. Computed values of pitch, heave, and roll are compared with experimental data from model tests of a catamaran in regular waves. Documentation of the computer program for predicting the roll of a catamaran in regular and irregular seas is presented.

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COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	SUMMARY
Johnson, R.B., Jr., Sigman, R., "Data Reduction Software for a Differential Maneuvering Simulator, User Guide to Computer Program HASTE," NSRDC Report No. 3841, April 1972.	Aircraft	Motions Prediction	The computer program HASTE is an executive program for the data display of the Differential Maneuvering Simulator (DMS). The DMS simulates two aircraft performing under direct pilot control and produces a complete time-history of the performance on a binary tape. The program HASTE interprets the binary tape into a meaningful form for analysis to evaluate.
Stanley, W., "Full Scale Design and Experimental Model Testing of a Waterjet Pump for a 500 Ton CAB testcraft. Volume 2., Waterjet System Dynamics," Rocketdyne Canoga Park, California, Report No. R-8391-2, January 1971.	Waterjet Propulsion	Dynamic Response	A portion of the study was the development of a digital-computer model containing non linear equations capable of determining the dynamic response characteristics of waterjet systems at both design and off-design operating conditions. This report contains only the technical background associated with development of the computer model.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Hubble, E.N., Nadler, J.B., "Prediction of Ship Motions in Regular and Irregular Head Waves," NSRDC Ship Performance Department, Report No. SPD-623-01, April 1975.	Displacement	Motions Prediction	Frank Close-Fit Ship Motion Computer Program
Applebee, T.R., Baitis, A.E., "Response Amplitude Operator Predictions for the USS Belknap (DLG-26) and USS Joseph Hewes (DE-1052) Class Destroyers," Naval Ship Research and Development Center, Report No. SPD-590-01, November 1974.	Displacement	Motions Prediction	The response amplitude operators, RAO's are computed for the ships in LAMPS (Light Airborne Multipurpose System) configuration and are to be used for ship motion predictions in ship/helicopter interface design.
Cox, G.G., Gersma, D.M., "A Comparison of Predicted and Experimental Seakeeping Characteristics for ships with and without large Bow Bulbs," NSRDC Report No. SPD-591-01, November 1974.	Displacement	Motions Prediction	Comparisons are made between predicted and experimental results for head wave longitudinal ship motions for three ship hulls, one of which possesses a large bow bulb. It is shown that although linearized potential strip theory is adequate for determining motion transfer functions of conventional ship hull forms, over prediction occurs for ships which possess large bow bulbs.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Baitis, A.E., Bales, S.L., Myers, W.G., "Preliminary Roll and Pitch Predictions for Two Candidate Hull Forms of T-AGS," NSRDC Ship Performance Department, Report No. SPD-576-01, August 1974.	Displacement	Motions Prediction	NSRDC Ship Motion and Sea Load-Computer Program.
Beukelman, W., and Duitenhek, M., "Full Scale Measurements and Predicted Seakeeping Performance of the Containership 'Atlantic Crown'," Netherlands Ship Research Centre TNO, Report No. 185 S, November 1973.	Displacement	Motions Prediction	TRIAL
Fujii, H., Takahashi, T., "Study on Lateral Motions of a Ship in Waves by Forced Oscillation Tests," Mitsubishi Heavy Industries, Technical Bulletin, No. MTB-87, August 1973.	Displacement	Motions Prediction	The effect of keels on ship motions was determined experimentally. These motions were compared to those calculated by the strip method

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Bales, S.L., Meyers, W.G., Rossignol, G.A., "Response Predictions of Helicopter Landing Platform for the USS Belknap (DLG-26) and USS Garcia (DE-1040) - Class Destroyers," NSRDC Report No. 3868, July 1973.	Displacement	Motions Prediction	Ship Motions and Sea Loads by Salvesen and NSRDC Irregular Sea Response Prediction Computer Program
Wahab, R., and Moss, L.W., "On the Motions of a Destroyer with a Large Bulbous Bow and a Wide Transom Stern," NSRDC Report No. 3717, June 1973.	Displacement	Motions Prediction	Gerritsma, J. and Beukelman, W., "Analysis of the Modified Strip Theory for the Calculation of Ship Motions and Wave Bending Moments," Ogilvie, T. Francis and Tuck, Ernest O., "A Rational Strip Theory of Ship Motions, Part 1." Vugts, J., "The Hydrodynamic Forces and Ship Motions in Waves."
Ogilvie, T., Beck R., "Transfer Functions for Predicting Ships Motions A Review of the Theory," University of Michigan, SNAME T&R Report, 1973.	Displacement	Motions Prediction	Various

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Bales, N.K., Cummins, W.E., "The Influence of Hull Form on Seakeeping," The Society of Naval Architects and Marine Engineers, No. 1, November 1970.	Displacement	Motions Prediction	ESP
Salvesen, N., Smith, W.E., "Comparison of Ship-Motion Theory and Experiment for Destroyer with Large Bulb," Journal of Ship Research, March 1970.	Displacement	Motions Prediction	Close-Fit computer program by W.E. Smith.
Salvesen, N., Smith, W.E., "Comparison of Ship-Motion and Experiment for Mariner Hull," NSRDC Technical Note No. 104, September 1969.	Displacement	Motions Prediction	The Frank Close-Fit Ship-Motion computer program.
Gersten, A., Johnson, R.J., "Notes on Ship Model Testing in Transient Waves," NSRDC Report No. 2960, April 1969.	Displacement	Motions Prediction	Computation of the transforms and transfer functions.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Wybro, P.G., and Seidl, L.H., "Comparison of the Swaying, Rolling and Yawing Response Operators Obtained from Computer Program ASYMO with Experimental and Theoretical Results," University of Hawaii, Department of Ocean Engineering, Technical Report No. 28, U Hawaii-Look Lab-72-28, October 1972.	Displacement	Motions Prediction	ASYMO
Seidl, L., "Comparison of the Surging Heaving and Pitching Response Operators Obtained from Computer Program REGW with Experimental Results," University of Hawaii, Department of Ocean Engineering, Technical Report No. 22 U Hawaii-Look Lab-71-22, November 1971.	Displacement	Motions Prediction	REGW
Salvesen, N., Smith, W.E., "Comparison of Ship-Motion Theory and Experiment for Mariner Hull and a Destroyer Hull with Bow Modification," NSRDC Report No. 3337, June 1971.	Displacement	Motions Prediction	The Frank Close-Fit Ship-Motion computer program.

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PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Kallio, James A., "Computer Study on the Seaworthiness Characteristics of High Speed Naval Vessels," NSRDC HML T&E Report No. C-227-H-07, November 1968.	Displacement	Motions Prediction	ZK11 program.
Mott.., Lewis E., "Computational Study on the Effect of Bulb Shape on Seaworthiness Characteristics of High Speed Naval Vessels," NSRDC HML T&E Report No. C-277-H-06, May 1968.	Displacement	Motions Prediction	Frank Close-Fit Ship-Motion program.
Gerritsma, J., Smith, W.E., "Full-Scale Destroyer Motion Measurements," Journal of Ship Research, March 1967.	Displacement	Motions Prediction	Modified Strip Theory
Kerivin, J.E., "Determination of Ship Motion Parameters by a Step Response Technique," Journal of Ship Research, Vol. 9, No. 3, December 1965.	Displacement	Motions Prediction	Computation of damping and vertual inertia at a given frequency.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Breslin, J. P., Savilsky, D., Tsakonas, S., "Deterministic Evaluation of Motions of Marine Craft in Irregular Seas," Davidson Lab. Steven Institute of Technology TN-723 Presented at Fifth Symposium on Naval Hydrodynamics, Bergen, Norway, September 1964.	Displacement	Motions Prediction	The heave and pitch time were computed on an IBM 1620 by evaluating the convolution integrals.
Wahab, R., Moss, L.W., "On the Motion Coefficients of a Destroyer Hull With a Large Bulbous Bow," NSRDC Department of Hydrodynamics T&E, Report No. 227H13.	Displacement	Motions Prediction	The Frank Close-Fit Ship Motion Computer Program
Stram, T.J., Yeh, H., Moran, D., "Added Resistance in Waves," Trans SNAME Vol 81, 1973	Displacement	Added Resistance	Frank Close-Fit Ship Motion Computer Program. Programs for added Resistance using Maruo's theory Joosens theory and Gerritsmas theory.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Wahab, R., and Moss, L.W., "On the Added Drag of Destroyers in Regular Head Waves," NSRDC Report No. 3704, August 1971.	Displacement	Added Resistance	Frank Close-Fit Ship Motion Computer Program.
Doust, D.J., "Ship Design and Power Estimating Using Statistical Methods," Norwegian Ship Model Experiment Tank, The Technical University of Norway, December 1962.	Displacement	Resistance	(DEVCE) regression equation
Joosen, W.P.A., "Added Resistance of Ships in Waves," Netherlands Ship Model Basin, Wageningen, The Neth :lands.	Displacement	Added Resistance	To determine the drift force and added resistance for an actual ship, a computer program has been written based on method by Joosen.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Kutter, M. L., "Prediction of Slamming Characteristics and Hull Responses for Ship Design," Trans SNAME Vol 81, 1973.	Displacement	Slamming	The prediction includes (a) frequency of occurrence of slam impacts, (b) time interval between successive impacts, (c) elapse time before the next severe impact will occur (d) magnitude of impact pressure (e) the largest (extreme value) impact pressure most likely to occur, (f) the extreme pressure for design consideration, (g) ship speed at which bottom plate damage is most likely to occur.
Jones, Robert R., Allen, Raymond G., "A Semiempirical Computerized Method for Predicting Three-Dimensional Hull-Water Impact Pressure Distributions and Forces on High-Performance Hulls", NSRDC Report No. 4005, Dec. 1972.	Displacement	Slamming	IPPRES

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Kaplan, P., Oceanics, Incorporated, Sargent, TP, "Further Studies of Computer Simulations of Slamming and Other Wave-Induced Vibratory Structural Loadings on Ships in Waves," Oceanics, Incorporated, ##SSC-231, July 1972.	Displacement	Slamming	Computer simulation of wave-induced structural loadings on ships in waves is presented.
Andrews, John N., "A Method for Computing the Response of a Ship to a Transient Force", DTMB Report No. 1544, November 1963.	Displacement	Slamming	A method for determining the elastic body response of a ship to a seaway is presented. The ship is divided into 20 equi-length sections. The force, generated by the seaway, which acts on the ship is computed for each of the 21 stations. The force is considered to consist of two parts, i.e., an unsteady hydrodynamic force. The force and mass-elastic parameters representing the hull are used as input quantities on the digital computer to obtain the response.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Abramson, H. Norman, Dalzell, J. F., "Hydrodynamics of Ship Slamming," Southwest Research Institute, September 1963	Displacement	Slamming	"Further Development of a More Accurate Method for Calculating Body-Water Impact Pressures" by Wen-Hwa Chu, and David R. Falconer, Tech. Rept. No. 5, January 1963
Leibowitz, Ralph C., "A Method for Predicting Slamming Forces on and Response of a Ship Hull" DTMB Report No. 1691, September 1963.	Displacement	Slamming	This report describes a method for obtaining digital computer solutions for the excitation forces on and transient response of a ship subject to (hydrodynamic) slam when certain basic data are obtained by computation rather than by measurement.
Lima, CG., "Multivariable Systems Design: A Two Ships Controller For Replenishment At Sea," Naval Postgraduate School, Monterrey, California, June 1974.	Displacement	Maneuvering	The mathematical model of the ships motion in three degrees of freedom is established and implemented for the formation of digital computer programs.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Eda, H.; Stevens Institute of Technology, "Maneuvering Characteristics of Large Tankers," Super Ocean Carrier Conference, January 1974.	Displacement	Maneuvering	The effect of inherent dynamic course stability on ship handling was examined for three ship configurations having various degrees of inherent stability through computer-based analysis.
Crane, C.L., "Maneuvering Safety of Large Tankers: Stopping, Turning, and Speed Selection," Trans SNAME Vol 81, 1973.	Displacement	Maneuvering	Ship trial results and computer simulation of emergency stopping and turning maneuvers are utilized in this study.
Davies, R.M., Lambert, T. H., "Coupling of Directional and Roll Motions of Surface Ships," Ecole Polytechnique, Canada, Proc. Paper, 1973	Displacement	Maneuvering (Motions Prediction)	An analog model used has been modified to include an active fin stabilizer and results are presented to show the effects of the cross coupling.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Dand, I.W., "Full Form Ships in Shallow Water: Some Methods for the Prediction of Squat in Subcritical Flows," National Physical Laboratory, Ship Division, Ship Report No. 160, January 1972.	Displacement	Maneuvering	Program to calculate mean sinkage and trim.
Van Randwijck, Eric F., "Equations of Motion for Mooring and Docking Trainer Based on Model Tests and Computer Simulation," NSRDC Report No. 382-H-02, January 1971.	Displacement	Maneuvering	Computer Program for a Mooring and Docking Trainer.
Eda, H., Crane, C.L., "Steering Characteristics of Ships in Calm Water or in Waves," Transactions SNAME VOL 73, 1965.	Displacement	Maneuvering	A digital computer is used to make nonlinear predictions of ship response to rudder action.
Goodman, A., Gertler, M., "Analytical and Experimental Techniques Used at HSMB for Surface - Ship Directional Stability and Control Studies," Hydrodynamics Inc., Technical Report 7500-1.	Displacement	Maneuvering	Computer simulation studies are performed at HSMB for each specific ship design for which a complete set of hydrodynamic coefficients resulting from the conduct of standard Planar Motion Mechanism.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Dinsenbacher, Alfred L., Perkins, Robert L., "A Simplified Method for Computing Vertical Hull Natural Frequencies and Modes in Ship Preliminary Design Stage," NSRDC Report No. 3881, January 1973.	Displacement	Vibrations	GBRC1
Perkins, Robert L., "Calculated Vertical Natural Frequencies and Normal Modes for Motor Gunboat USS Asheville (PC-84)," NSRDC Report No. 2753, June 1968.	Displacement	Vibrations	Calculating vibration parameters for surface ships.
Viner, John G., "The Significance of Shell-Like Vibration of NS Savannah at Low Frequencies", DTMB Report No. 2152, March 1966.	Displacement	Vibrations	Computer Engineering Associates. The CEA study used a passive electrical analogy to examine the vibratory characteristics of SAVANNAH. The structural model considered the stress-carrying system as composed of a combination of the following simple elements: axial members, flexural members, and shear panels.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
McGoldrick, Raymond T., "Calculation of the Response of a Ship Hull to a Transient Load by a Digital Process" DTMB, Report No. 1119, March 1957.	Displacement	Vibrations	Polacheck, Harry, "Calculation of Transient Excitation of Ship Hulls by Finite-Difference Method"
McGoldrick, Raymond T., "Calculation for Hull Vibration of the SS Gopher Mariner and Comparison with Experimental Results", DTMB Report No. 1022, May 1956.	Displacement	Vibrations	Kapiloff, E., "Calculation of Normal Modes and Natural Frequencies of Ship Hulls by Means of the Electrical Analog."
Cotton, J., "Conceptual Design of Ships Model (CODESHIP). Volume I, Background and Method of Analysis, Dec. 71, Report No. SEG-Research Contrib - 159 - VI	Displacement	Tech & Cost Characteristics	CODESHIP
Day, W.G.,Jr., "Change of Level Predictions for an LPD-4, ANLST 1179 and a Cargo Ship Operating in Shallow Water," NSRDC SPD T&E Report No. C-330-H-02, February 1971.	Displacement	Sinkage	A computer program which calculates the sinkage length ratio and the trim angle - Tuck, E.O., Slender Bodies," Journal of Fluid Mechanics, Vol 26, Part I, Sept. 1966.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Savitsky, Daniel, and Breslin, John P., "Motions of High-Speed Hydrofoil Craft in Irregular Seas," SNAME Hydrofoil Symposium, 1965 Spring Meeting.	Hydrofoil	Motions Prediction	"An IBM Program for the Fourier Transform of a Complex Function of Frequency." "An IBM Program for the Convolution of Two Functions of Time."
Bernicker, R.P., "Deterministic Predictions of the Motions of a Hydrofoil Craft in Irregular Seas," Stevens Institute of Technology, Davidson Laboratory, Report No. 1003, January 1964.	Hydrofoil	Motions Prediction	"An IBM Program for the Fourier Transform of a Complex Function of Frequency." "An IBM Program for the Convolution of Two Functions.
Langan, Thomas J., and Wang, Henry T., "Evaluation of Lifting-Surface Programs for Computing the Pressure Distribution on Planar Foils in Steady Motion," NSRDC Report No. 4021, May 1973.	Hydrofoil	Pressure distribution on planar foils	Tulinius Dulmovits Margason-Lamar Giesing Rubbert Lopez & Shen Haviland Jordan Lamar Widnall Bandler Rowe Cunningham Jacobs-Tsakonas Lopez (Kuchemann)

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Kaplan, P., Sargent, T.P., "Determination of Stability Derivatives of Hydrofoil Craft Via System Identification," Oceanics Inc., Report No. 72-93, October 1972.	Hydrofoil		Trajectory Data Supplied from computer simulation (with known coefficient values) computer program to simulate trajectory data required known coefficient values.
Kaplan, P., Bentson, J., Sargent, T.P., "Advanced Loads and Motions Studies for Surface Effect Ship (SES) Craft, Part I. General Development of Modified Mathematics Model," Oceanics Inc., Report No. 73-98A, June 1973.	SES	Motions Prediction	Comparison of predicted motion in waves with available model test data shows a sufficiently good prediction capability that validates the use of the mathematical model and the associated digital computer program.
Bratanow, Theodore, "Application of Computer Methods in Air Cushion Vehicle Research, Kansas University, No. AD 689 554, April 1969.	SES	Motions Prediction	Numerical solution of differential eq.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Lin, J.D., "Dynamic Behavior of Ground Effect Machines in Motion Over Water, Journal of Ship Research April 1963.	ACV	Motions Prediction	A program prepared at Hydronautics allows study of dynamic stability of a machine through variation of pertinent parameters and also investigation of its dynamic response to various wave encounter conditions (See Hydronautics Tech Report 011, 3 March 1962).
Sheng-Lun, C., "Slamming Tests of Three-Dimensional Models in Calm Water and Waves," Naval Ship Research and Development Center, 4095, September 1973.	SES	Slamming	A prediction method is being developed at the Naval Ship Research and Development Center (NSRDC) for determining wave impact loads when a high performance vehicle experiences slamming while traveling at very high speeds. This method is based on the Wagner wedge impact theory, and NSRDC drop tests of wedges and cones.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
"500 Ton Arctic Sev Configuration Study Volume 1, Program Summary," Boeing Co., Report No. D180-18139-1, August 1974.	SES	Maneuvering	Dynamics Computer Simulation and a visual flight simulator to evaluate vehicle maneuvering, control and display with the pilot-in-the-loop, and a relatively low risk vehicle design has been developed which meets or exceeds all major requirements.
Mansour, A., Choo, K., "Motion and Loads Prediction of Catamarans In Random Seas," Massachusetts Institute of Technology, Department of Ocean Engineering, Report No. 73-6, April 1973.	Catamaran	Motions Prediction	CAT-5
Jones, Harry D., "Analytical Comparisons of Catamaran and Monohull Motions in Head Seas," NSRDC SPD T&E Report No. 072-H-11, March 1972.	Catamaran	Motions Prediction	Frank Close-Fit Ship-Motion computer program & CATI.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Jones, Harry D., "Catamaran Motion Predictions in Regular Waves," NSRDC Report No 3700, January 1972.	Catamaran	Motions Prediction	CAT1, Modified YF17 (Frank Close-Fit Ship-Motion computer program) - HJCT, and RLAC.
Pien, P.C., Lee, C.M., "Motion and Resistance of a Low-Waterplane Catamaran," Ninth Symposium Naval Hydrodynamics, ACR-203.	Catamaran	Motions Prediction	Analytical method has been developed for predicting characteristics of motion and hydrodynamic loads of catamarans, either conventional or SWATHS.
Chin Lin, W., Day, Jr., W.G. "The Still-Water Resistance and Propulsion Characteristics of Small-Waterplane-Area Twin-Hull (Swath) Ships," AIAA/SNAME Advanced Marine Vehicles Conference, AIAA Paper No. 74-325, February 1974.	Catamaran	Added Resistance	Propulsion characteristics. A theory to predict the wave resistance of the SWATH ships

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Sherman, T., Fisher, P.A., "A Study of Planing Catamaran Hull and Tunnel Interaction," Michigan Univ., Ann Arbor Ship Hydrodynamics Lab., Report No. 011073-1-F, February 1975	Catamaran	Power	A computer program for the prediction of power for prismatic planing boats has been modified to include catamarans.
Jones, R.R., Allen, R.G., "A Semi-empirical Computerized Method For Predicting Three-Dimensional Hull-Water Impact Pressure Distributions and Force On High-Performance Hulls, "Naval Ship Research and Development Center; Structures Department, ##1005, December 1972.	Planning	Water Pressure Distribution	Computerized method for calculating instantaneous three-dimensional water pressure distributions on high-speed marine vehicles.
Salvesen, Nils, and Schot, Joanna W., "Recommendations for Advancing the Capability in Numerical Naval Hydromechanics at NSRDC", NSRDC Tech. Note No. CMD-26-73, July 1973.	Various	Various	The Frank Close-Fit Ship-Motion Computer Program. Pien, P.C. and C.M. Lee, "Motion and Resistance of a Low-Waterplane-Area Catamaran. Salvesen, N., E.O. Tuck, and O.Faltinsen, "Ship Motions and Sea Loads."

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Salvesen, N., von Kerczek, C. H., "Numerical Solutions of Two-Dimensional Nonlinear Wave Problems," Presented at the ONR 10th Symposium on Naval Hydrodynamics at MIT, June 1974.		Wave Resistance	The nonlinear free-surface effects on the two dimensional potential flow past a distrubance is examined by a direct numerical procedure and a perturbation technique. The last of these is used in the present method simply because it is very easy to program and is very reliable.

TABLE 2

PUBLICATIONS REFERENCING COMPUTER PROGRAMS IN SHIP DYNAMICS

AUTHOR/TITLE	SHIP TYPE	TOPIC	COMPUTER PROGRAM
Hershey, A. V., "Computing programs for Surface Wave Trains of Point Sources," US Naval Weapons Laboratory, Report No. 1987, June 1965.			Descriptions are given for four programs which compute the components of velocity in the wave train of a unit source. The program gives the velocity at an arbitrary position in any direction and at any distance from the source.

APPENDIX C

This appendix includes a description of the four programs recommended by the Ship Performance Department for use in ISDS. The description of each program includes the input requirements, output, typical running time, and general discussion of the program.

ENTRY AND SOLUTION PROGRAM (ESP)

ESP utilizes a standard series approach to estimate pitch and heave motions in head seas. It was developed by N. K. Bales of DTNSRDC.

ESP allows determination of trends in seakeeping responses with changes in hull geometry at an early stage in the design process. The seakeeping responses considered are heave, pitch, and the amplitude and acceleration of vertical motions near the bow. The user inputs the significant wave height (average of the one-third highest waves) representative of the sea state of interest, and the program uses the Pierson-Moskowitz wave spectrum to compute each response at the input speed and at speeds corresponding to Froude numbers of 0.1, 0.2, and 0.3.

ESP requires the following input:

Ship geometry:

- length between perpendiculars
- beam
- draft
- nominal sectional area coefficient at forward perpendicular
- nominal sectional area coefficient at aft perpendicular
- waterplane coefficient forward of midship
- waterplane coefficient aft of midship
- midship section coefficient

Significant wave height

Ship speed (knots)

Set of response weighting factors (optional):

W1-weighting factor for rms heave
W2-weighting factor for rms pitch
W3-weighting factor for rms relative motion
W4-weighting factor for rms absolute acceleration

The output from ESP is:

RMS heave amplitude (ft)
RMS pitch amplitude (ft)
RMS relative motion (ft) } at 10% of ship length
RMS acceleration (ft/sec^2) } (Station 2)
Seakeeping efficiency, a composite measure obtained by applying weighting factors to the above four motions.

The weighting factors are used only to emphasize the relative importance of the different motion responses in the computation of seakeeping efficiency, an emperical measure of overall seakeeping ability. The assignment of weighting factors is a value judgement which the designer must make on the basis of the mission requirements which he is attempting to satisfy. If, for instance all four responses are considered to be equally important, he should assign a weight of 1 to each response. If on the other hand, relative motion is considered to be significantly more important than the other responses he might assign it a weight of 5 and the other responses weights of 1.

The current data base is limited to single screw cargo hulls with either conventional sterns or transom sterns. To extend this data base, say to destroyers, would cost approximately 60K per class of ships.

On the CDC 6700 computer, this program requires 71,200 octal words to load and a maximum of 40 cpu seconds to run, however this program has not been optimized for either minimum memory or running time.

CONOLLY ROLL PROGRAM

The Conolly Roll Program is an unpublished roll program in which it is assumed that the ship is wall sided at the waterline and that distributed along its length are buoyancy forces whose magnitudes are determined by the local sectional areas. The local buoyancy forces are assumed to act normal to the local wave surface. This theory involves a number of simplifying assumptions, and in view of these it is considered justified for ease of solution to replace the ship by a simple equivalent shape having rectangular sections and a constant draft. For fine warship forms, the waterline width can be reasonably represented by a parabola having maximum half-breadth at the mid-length and zero half-breadth at the ends. This shape tends to over-estimate the width of the forebody, and under-estimate that of the afterbody. Elliptical and rectangular waterplane shapes are also available.

This program gives the rolling motion and righting arm moment of the ship in regular waves of any selected length and height. Any energy spectrum of wave slope may also be specified to give a distribution of motion in irregular waves. In irregular waves the response amplitude operator, the RMS roll, and the heeling moment are calculated.

The input for the Conolly Roll Program is as follows:

Ship geometry:

- length between perpendiculars
- beam
- draft
- center of buoyancy
- metacentric height
- natural roll period
- coefficient of roll decay
- ratio of hydrodynamic inertia to ship inertia

Speed

Significant wave height

The output for this program is the RMS Roll Amplitude of the ship to regular waves for every 15° of heading.

On the CDC 6700 the program requires 16,200 octal words to load. A typical run to analyze three ship speeds at headings of every 15 degrees requires about 25 seconds of computer time.

FRANK CLOSE FIT SHIP MOTION COMPUTER PROGRAM

As was stated in paragraph IV.B.2, there are a large number of programs for the calculation of pitch, heave and loads. These programs are based on the same theories, and all calculate approximately the same outputs. The program input format, size, and running time may vary from program to program but the calculations are all similar. The specific program recommended for performing the calculation is the Frank Close Fit Ship Motion Computer Program. This program is recommended, even though it is difficult to say that one program is better than the other, because of familiarity of navy personnel with this program. The Frank Close Fit Ship Motion Computer Program does not at present calculate some design information (slamming, deck wetness, propeller emergence) that would be useful. Including these design features would be only a small extension of the present program.

The geometry of the ship stations may be defined by two different methods, namely:

a. by giving about eight offset points for each station, or

b. by giving the beam, the draft and the area coefficient of the cross sections

Note that it is not necessary that the same method be used for the entire ship.

If a station is represented by offset points, the user then has the freedom to select between the close-fit method or the Lewis-form method in the computation of the sectional added mass and damping coefficients. When the Lewis-form method is selected, the computer scans the offsets for each section to determine the local beam, draft, and sectional area, and a Lewis form matching those parameters is selected for the section.

In addition to the information about the geometry of the ship, the user also must select the conditions for which he wants the computations performed. For regular wave output he must select the ship speeds and the range of encounter frequencies.

For irregular sea computations it is necessary to specify the ship speeds, ship length, the significant wave height, and the longitudinal locations at which motion responses are to be calculated.

The Pierson-Moskowitz sea spectrum is expressed in this program as a function of the significant wave height.

The program is designed so that irregular sea responses can be computed at six different ship lengths for the same given ship form without any changes to those data cards which give the geometry of the ship form.

The input for the Frank Close Fit Ship Motion Computer Program is as follows:

Ship geometry:

- longitudinal radius of gyration
- length between perpendiculars
- geometric description of an adequate number (less than 30) of ship stations, either as offsets or as the beam, draft, and area coefficient for each station

For regular waves:

- Froude number
- range of encounter frequencies

For irregular waves:

- significant wave heights
- range of ship speeds
- points along ship for which motion responses are to be calculated

Output from this program:

- coefficients and forces in the equations of motion for pitch and heave

For regular waves:

- pitch and heave amplitudes and phases over range of encounter frequencies
- plots of pitch and heave amplitudes and their phase angles as a function of wave length

For irregular waves:

- the average, significant, and 1/10 highest amplitudes of pitch and heave
- the absoute and relative vertical displacement velocity and acceleration at any point along the length of the ship

Properties of input hull form:

- block coefficient
- displacement
- longitudinal center of buoyancy
- longitudinal center of flotation
- sectional beam
- sectional draft
- sectional area coefficient
- plot of section shapes

The typical running time for this program using 20 stations and 40 frequencies is 500 CPU seconds on the CDC 6700 however, if all Lewis form sections are used the running time is reduces to about 50 CPU seconds. The running time is proportional to the number of stations and frequencies used.

DTNSRDC Ship-Motion and Sea Load Program

This program is a general six degree of freedom motion program from which the portion of the program for calculating roll can be removed. The reason for not using this program as is for the calculation of pitch and heave as well as roll is that the program is a research tool providing much more information than is needed for design, and it is very time consuming to run.

The NSRDC Ship Motion and Sea Load Computer Program in its present form predicts the roll motions for conventional cruiser stern hull forms at moderate speeds in beam seas with reasonable accuracy[4].

In order to calculate roll motions which are reasonably accurate in the frequency range close to resonance it is necessary to obtain good estimates for the viscous roll damping coefficients used in the equation of motion. The total and sectional viscous roll damping coefficients are not generally available for most ship forms and they are extremely difficult to obtain.

Non-linear viscous roll damping is introduced in the six-degree of freedom equations of motion in the form of a quasi-linear term which is added to the linear damping coefficient. This quasi-linear term depends on the frequency of encounter, the viscosity, the bilge keel dimensions, the hull geometry, and the maximum roll angle.

The program uses a trial and error procedure for solving roll motions. First the roll responses are computed using an estimated value for the maximum roll angle keeping the wave slope constant, then the program compares the maximum computed roll amplitude with the estimated value. If the

difference is larger than one degree, a new value for the maximum roll angle is estimated by the program and the computations are repeated until the difference between estimated and computed maximum roll amplitude is less than one degree.

The input for the roll portion of the NSRDC Ship Motion and Sea Load Computer Program is as follows:

- offsets on 21 stations
- mass of ship
- roll and yaw radii of gyration
- mass product of inertia about the X and Z axes
- vertical and longitudinal centers of gravity
- total length of submerged portion of the hull
- classification of each section shape (e.g., deep V, extremely rounded sections, etc.)
- dead rise
- bilge radius
- bilge keel description (See Figure 3)
  - length and width of bilge keel
  - angles α and ϕ
  - girth distance (G) from bilge keel to DWL
  - distance (D) from bilge keel to a longitudinal axis through the CG.

The output from this program is:

- the coefficients and forces in the roll equation of motion
- the roll amplitude as a function of frequency of encounter

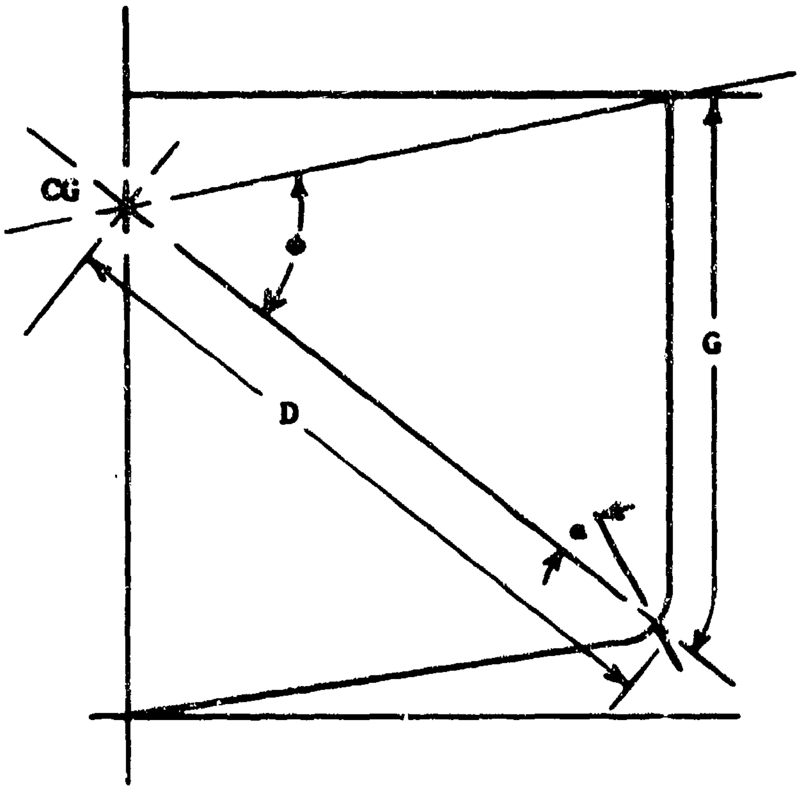

Figure 3 - Typical Ship Cross Section Illustrating the Geometric Parameters Required to Describe the Location and Orientation of the Bilge Keels

- the roll response amplitude operators (gives roll amplitude as a function of wave height)

- the roll non-dimensional transfer functions (gives roll amplitude as a function of wave slope)

The estimated time to run this program for roll motion is less than 60 seconds.

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